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SOLAR MOBILE HOME HEATING

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September, 1979

Prepared for

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INTRODUCTION

The goal of this project was to explore the application of solar heating to a factory-built mobile home. The project consisted of three basic phases: (1) design phase; (2) construction phase; and (3) performance monitoring phase. The design phase began in July 1978 and the construction phase began in September 1978. The home was occupied in October and the solar system was started up in December 1978. Monitoring instrumentation was installed in December and performance data was collected from January 1979 until September 1979. Data processing and interpretation has followed the monitoring period. The purpose of this report is to present the results of the performance monitoring and to summarize the results of this research.

The solar heating system was designed primarily to meet the research and testing objectives of this project. We also tried to develop a design that might be considered a first prototype of an eventual production model. If a solar heating system could be integrated into the mobile home structure at the factory, significant savings would be achieved. The results indicated that while the collector system performed very satisfactorily, the heat storage system was inefficient and severely penalized the overall performance.

DESCRIPTION OF THE PROJECT

A photograph of the south side of the mobile home is shown in Figure 1 and the floor plan and site location in Figures 2 and 3. The mobile home was manufactured by Gallatin Homes Corporation in Belgrade, Montana. The unit is a low-energy model and features R-20 walls and floor, R-38 ceiling and double-glazed windows. The outside dimensions of the unit are 14' by 56'. This particular floor plan was selected because much of the south wall was available for mounting collectors.

SOLAR SYSTEM

The solar/wood/electric system is shown in Figure 4. The heat storage system is a conventional rock bin located partially in the ground under the mobile home. The top of the rock bin averages 12 inches above grade. Construction details are given in Appendix V. The two-fan system will deliver solar or wood heat directly to the house or to the rock bin storage depending on control signals from the thermostats. Figures 5 and 6 depict the solar-to-storage and wood heat-to-storage modes of operation. Figure 7 depicts the system mode in which heat is delivered to the house from the heat storage bin

(and the auxiliary electric furnace, if required). Additional schematics of the modes of operation of the system are shown in Appendix I.

The collectors are double glazed with low-iron glass and the air flows behind a corrugated absorber plate painted flat black. There are three banks of collectors, the two west banks being connected in series, Figure 5. A pictorial cut-away view of the construction of a typical collector bank is shown in Figure 8. Construction details are given in Appendix VI.

The wood stove is situated in a plenum chamber next to the auxiliary furnace, Figure 6. A photograph of the stove and plenum chamber is shown in Figure 9 and construction details are given in Appendix VII.

The schematic of the control system is shown in Figure 10. The collector fan and dampers are controlled by a differential thermostat. The wood stove damper and fan is controlled by a fan thermostat in the plenum chamber. A two-stage thermostat in the house controls the house fan, damper and auxiliary electric furnace. A photograph of the control system is shown in Figure 11.

Additional descriptive information on this system is contained in design reports prepared for the Department of Natural Resources and Conservation during the design phases of this project.

PERFORMANCE MONITORING

The instrumentation layout is shown in the schematic in Figure 12. Twenty channels of data were sampled each six seconds and hourly average data was recorded on cassette by the data acquisition system shown in Figure 13. Data included solar insolation in the plane of the collector, electric power input to the house and the status of the three motorized dampers and electric furnace. Air temperatures were measured at the inlets and outlets of the collectors, plenum, house and storage system. The house temperature and the outside ambient air temperature were also measured.

The air flow in the system was measured at several stations for the various operating modes of the system. A hot-wire anemometer was used for these measurements and a complete listing of the flow data is contained in Appendix I.

Using the flow rates and temperature differences, the heat flows in the system could be calculated. The appropriate equations were coded into the data acquisition system and computed on-line. A complete discussion of these equations is given in Appendix II.

DATA SUMMARY

The hourly raw data was processed and summarized to produce hourly-average energy or power quantities. These energy quantities are computed in units of mega joules (MJ). The output format of the tables of data are shown in Table 1. This table is an hourly summary for 24 hours on January 26, 1979. The definitions of the headings are:

SOLAR INSO: Total insolation or radiation striking collectors

SOLAR OUTPUT: Collector output

SOLAR STORE: That part of SOLAR OUTPUT going into the rock bin heat storage

WOOD STORE: Wood heat directed to storage

STORE HOUSE: Stored heat going into house

SOLAR HOUSE: Collector output going directly to house

WOOD HOUSE: Wood stove output going directly to house

ELECT HOUSE: Electric heat to house

SUMM INPUT: Sum of above four quantities, equal to total heat going into house

HEAT LOAD: Calculated heat loss factor for house multiplied by measured temperature differences

HOUSE TEMP: Average air temperature in house, ^{o}C

AMBT TEMP: Outside air temperature

COLL OUT: Collector outlet temperature

PLEN TEMP: Temperature of plenum chamber (where stove is located)

PLEN STORE: Duct temperature between plenum and storage bin

TO HOUSE: Temperature in house supply duct

CRAWL SPACE: Temperature in crawl space

FR, HS, CL, WD: Status of furnace and three motorized dampers: house, collector and wood stove.

Additional tables of daily performance summary are shown in Appendix III. The bottom line of the daily tables contains values for the daily totals of all energy quantities. These daily totals are further combined into tables of DAILY PERFORMANCE SUMMARY for each month. These summaries are given in Tables 2 through 7. Days having suspect data have been omitted from these summaries.

To gain an overview of system performance, these values are summed and averaged into monthly totals and given in Table 8. You should keep in mind that the typical entry in this table represents an average of about 250,000 individual readings.

System performance factors based on Table 8 are shown in Table 9. The overall distribution of heat loads is shown in Table 10 and the solar collector efficiency curves are shown in Figure 14.

DISCUSSION OF RESULTS

The collector efficiency curves in Figure 14 show data points taken near noon on clear days. These measured values agree with the expected performance for this type of air collector. The low-iron glass may explain the fact that the experimental values are a few percent high. From these curves we can conclude that the collectors are satisfactory.

The daily collector outputs in Figure 15 show that the collectors deliver around 35% of the incident radiation on days when they operate. The collector output on a monthly-average basis drops to 20 to 30%, Table 9. Study of the hourly data in Appendix III shows that this reduction may be partially due to improperly operating controls. There are days when the collector outlet temperature is relatively high but the fan does not go on.

Table 9 shows the major system problem to be storage efficiency, column 3. On a monthly basis only 10 to 20% of the heat sent to the rock storage bin returns to the house. The problem of heat loss from storage was identified in the design phase and great care was taken to insulate the heat storage chamber. Appendix IV outlines the heat loss calculations and Appendix V details the construction of the rock bin.

The primary storage heat loss appears to be due to air leaks rather than conduction. The graphs of crawl space temperature in Figures 16, 17 and 18 show evidence of the crawl space temperature changing when the fan turns on. This is due to air leaks.

The solar system efficiency in Table 9 was 45% in January and February. Most of the 55% deficit was due to losses in the storage system. The solar system efficiency decreases through the spring and becomes zero in July. This decrease is due to the reduced demand for heat by the house (which becomes zero in July).

The distribution of heat sources in Table 10 shows that the solar system is only supplying about 15% of the heat load. This is far short of the design goal of 50% solar fraction. The data shows that if the storage losses were reduced to zero, the solar fraction would increase by a factor of two to three. Improvements in the control system would further increase the solar fraction.

The auxiliary wood heat was used primarily in January and February, supplying 25 to 30% of the heat load. About 30% of the wood heat generated was sent to storage, where only about a net 4% was returned. The storage system thus penalized the wood heat delivered by about 25%.

The original test program included a phase where electric heat was to be sent to storage during off-peak hours. This test phase was omitted. Due to the large storage losses, it would have been a waste of energy. The hot water pre-heat tank in the rock bin was not connected. Because of the extremely low temperatures last winter, it was necessary to use heat tape and an electric heater to keep the water supply plumbing from freezing. The hot water tank plumbing would have required more auxiliary electric heating and was judged a poor investment.

CONCLUSIONS

(1) Air leaks were a major problem in this system. These leaks reduced collector efficiency and severely reduced storage efficiency. Air leaks into the house during the initial three months of testing caused over-heating of the house.

(2) The storage system in this design was located outside the heated envelope in order to save interior space. The heat losses associated with this system were large and contributed little to the mobile home since the losses went into the crawl space.

(3) At this point, it appears that the heat storage must be located within the heated envelope to achieve a high thermal efficiency. The cost of this inside space would penalize the economics of the solar system. For these cold climates an adequately-sized storage of minimum volume would point to the necessity of using a phase change material (PCM) for heat storage. The cost of this material would further penalize the solar economics.

(4) Coupling the wood heat system to the storage also requires that the storage be efficient. It is further necessary for the occupants of the home to actively schedule the use of the wood heat to make this feature worth the cost of the extra duct work. The occupants must know when the storage is discharged and then take appropriate steps to charge the storage with the wood heat. This may be asking too much of the average person.

(5) The noise of the system's two fans was distracting to the occupants. This noise could be reduced by using lower-speed fans and attaching the fans with flexible mounts.

RECOMMENDATIONS

Based on the results of this project, the following recommendations are made to a potential manufacturer of solar-heated mobile homes for Montana:

(1) Use vertical air collectors on the south wall. Integrate these collectors into the wall construction, taking care to minimize air leaks.

(2) Dedicate space inside the trailer for the heat storage chamber. Integrate this chamber into the structure of the trailer.

(3) Use phase change material (PCM) technology for the heat storage to minimize the interior volume required. This type of storage will use about 30 square feet of floor space or about 240 cubic feet of interior volume.

(4) Put a door or access panel on the heat storage chamber so that the PCM modules can be loaded into the home after the home is set up. This will reduce travel weight during delivery.

(5) Insulate and seal the walls of the heat storage chamber to control heat coming into the mobile home. Gypsum lining is recommended.

(6) Design collectors, components and sealants to withstand at least 250°F. The operating collector air temperature will be up to 180°F.

(7) Situate the system fan(s) so that the fan motor(s) will not be subjected directly to the solar-heated air at collector or storage outlets.

(8) Keep duct work inside the insulated envelope and seal carefully to minimize air leaks.

(9) If glass is used for collector glazings, design the glazing so that it can easily be removed for transporting the mobile home.

ALTERNATE RECOMMENDATIONS

Some thought should be given to a passive approach to solar heating of mobile homes along lines recently developed at M.I.T. Ceiling panels of PCM would be used for heat storage and the panels would be installed after the house is sited. Solar radiation would enter glazed wall panels. Heat loss control and shading would be provided by interior, insulated panels. Off-peak electrical resistance heating could be provided by incorporating the resistance wires in the ceiling next to the PCM.

TABLE 1

SAMPLE HOURLY DATA SUMMARY FOR ONE DAY

DAILY PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 1/ 23/79

HR	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SWHR INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FR HOURLY	HS	CL	UD STATUS
1	.0	.0	.0	.0	.0	.0	6.3	.8	7.1	13.9	18.7	-14.0	47.4	61.7	22.6	12.6	4.1	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	5.4	2.6	7.9	13.5	18.2	-15.7	45.6	56.8	21.7	12.1	3.7	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	4.8	1.2	6.0	12.8	17.9	-14.1	44.5	54.1	21.0	11.7	3.6	.0	.0	.0	.0
4	.0	.0	.0	1.5	.0	.0	5.6	.6	6.3	13.5	19.4	-14.3	41.6	58.2	23.5	12.8	3.7	.0	.0	.0	.1
5	.0	.0	.0	.0	.0	.0	5.5	2.6	8.1	13.6	18.8	-15.3	46.8	57.6	20.7	11.5	3.5	.0	.0	.0	.0
6	.0	.0	.0	1.5	.0	.0	5.7	1.2	6.9	13.3	19.1	-14.3	41.8	58.6	23.2	12.6	3.8	.0	.0	.0	.1
7	.0	.0	.0	1.5	.0	.0	5.2	.7	5.9	13.1	19.0	-13.8	43.6	54.2	22.2	12.2	3.5	.0	.0	.0	.1
8	.0	.0	.0	.0	.0	.0	6.4	2.1	8.5	13.1	18.9	-13.7	46.6	61.9	21.4	11.7	3.6	.0	.0	.0	.0
9	4.3	.0	.0	.0	.0	.0	5.8	5.3	11.1	13.7	19.5	-14.7	48.1	59.1	19.7	10.9	3.1	.0	.0	.0	.0
10	19.2	.0	.0	1.9	.0	.0	6.1	5.0	11.2	13.1	19.5	-13.2	49.7	60.7	21.7	11.7	3.1	.0	.0	.0	.1
11	61.8	7.4	4.7	5.3	.0	2.7	.0	10.2	12.8	11.8	20.6	-9.1	47.7	51.9	40.0	20.5	4.3	.0	.0	.3	.2
12	97.0	41.2	31.5	.0	.0	9.7	.0	3.7	13.4	14.2	26.6	-8.9	70.9	65.9	65.9	34.8	7.3	.0	.0	1.0	.0
13	116.2	56.0	25.5	.0	.0	30.5	.0	3.0	33.5	14.1	31.1	-9.3	92.5	69.6	69.0	43.2	9.3	.0	.0	1.0	.7
14	113.0	61.7	19.0	.0	.0	42.8	.0	4.6	47.4	17.5	34.7	-9.2	102.7	64.9	53.4	46.9	10.8	.0	.0	1.0	1.0
15	98.0	56.3	14.6	.0	.0	41.7	.0	3.3	45.0	16.2	35.7	-9.8	97.2	63.1	48.4	44.5	11.2	.0	.0	1.0	1.0
16	73.5	44.9	10.3	.0	.0	34.6	.0	3.4	38.0	18.6	34.9	-11.5	83.0	55.7	42.6	40.4	10.9	.0	.0	1.0	1.0
17	3.2	2.7	3.2	.0	.0	-.5	.0	2.4	1.9	17.1	28.3	-14.5	27.1	32.2	30.8	24.6	9.6	.0	.0	.6	.0
18	.0	.0	.0	.0	.0	.0	.0	8.7	8.7	16.2	25.7	-14.7	26.4	31.1	30.8	19.4	7.2	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	.0	4.8	4.8	17.2	24.7	-18.4	23.6	29.5	30.2	18.7	6.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.1	.0	.0	4.2	4.3	16.0	22.3	-17.7	22.6	30.4	29.5	18.0	5.1	.0	.0	.0	.0
21	.0	.0	.0	1.3	.0	.0	5.0	4.8	9.8	14.9	21.7	-15.5	40.9	55.2	30.1	16.0	4.8	.0	.0	.0	.1
22	.0	.0	.0	5.2	.0	.0	4.8	3.2	8.0	14.3	21.9	-13.8	31.1	54.0	33.7	18.7	4.8	.0	.0	.0	.2
23	.0	.0	.0	.0	.0	.0	6.2	2.5	8.7	15.2	22.1	-16.0	44.7	61.2	30.5	15.5	4.8	.0	.0	.0	.0
0	.0	.0	.0	6.9	.0	.0	4.9	4.2	9.1	15.6	22.1	-17.0	29.9	54.4	34.4	19.4	4.8	.0	.0	.0	.3
	586.1	270.1	103.7	25.1	.1	161.4	77.9	85.1	324.5	356.7	23.4	-13.8	49.8	54.5	32.4	20.9	5.7	.0	.0	.2	.2

TABLE 2

DAILY PERFORMANCE SUMMARY FOR JANUARY

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 1/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FP	HS	CL	WD
																		DAILY STATUS			
6	.0	1.1	.2	1.2	.8	.8	28.0	87.6	117.3	91.2	19.7	-25.9	41.9	62.4	17.5	14.0	4.0	.0	.1	.0	.0
7	651.1	74.7	61.5	9.1	1.6	13.2	95.4	427.4	537.5	435.5	21.2	-24.5	39.9	53.5	23.8	16.9	4.9	.0	.0	.2	.0
8	645.8	89.2	50.6	.0	.0	38.7	29.7	407.6	476.0	407.8	21.8	-20.7	29.7	36.6	22.0	15.8	5.5	.0	.0	.2	.0
9	91.6	.0	.0	.0	.0	.0	9.5	399.9	409.4	349.6	20.8	-15.6	18.2	26.7	15.3	12.7	6.0	.0	.0	.0	.0
10	91.6	1.0	.2	.0	.0	.8	69.7	323.5	394.0	289.4	21.6	-9.9	36.1	43.2	13.3	13.6	8.0	.0	.0	.0	.0
11	95.9	.0	.0	.0	.0	.0	37.7	276.2	313.8	244.4	23.9	-1.5	28.2	34.8	12.6	14.6	9.0	.0	.0	.0	.0
12	316.5	12.0	3.9	.7	.0	8.1	17.7	209.6	235.3	131.9	22.0	-14.1	22.2	30.0	10.6	9.1	2.9	.0	.0	.0	.0
13	137.5	.0	.0	.0	.0	.0	68.5	80.8	149.3	359.3	22.1	-15.3	28.8	41.3	10.9	13.4	11.3	.0	.0	.0	.0
14	317.5	7.4	1.8	.0	.0	5.5	65.1	74.3	144.9	392.6	22.4	-18.5	30.7	45.4	11.9	13.5	11.9	.0	.0	.0	.0
15	163.0	.8	.1	.0	.0	.7	78.1	82.4	161.1	308.9	21.9	-10.3	29.9	42.5	11.5	14.2	13.9	.0	.0	.0	.0
16	677.7	134.3	123.8	18.3	.0	10.5	69.2	67.8	147.5	294.9	24.3	-6.4	43.3	47.8	27.7	22.7	16.3	.0	.0	.2	.0
17	599.9	66.9	33.8	17.8	2.0	33.1	57.6	127.5	220.2	325.2	22.5	-11.4	34.5	42.6	27.9	22.1	12.2	.1	.1	.2	.1
18	393.2	55.1	57.1	41.2	1.7	2.0	85.9	197.9	283.5	275.1	22.7	-8.5	36.1	50.6	30.0	23.3	11.0	.0	.0	.3	.1
19	101.2	.0	.0	56.8	3.5	.0	135.3	197.6	336.3	294.3	23.5	-7.2	38.1	58.0	30.7	22.9	12.9	.0	.0	.0	.1
20	126.8	.0	.0	52.5	.0	.0	99.1	194.3	293.4	212.9	23.0	-1.2	37.4	53.0	29.2	23.3	14.9	.0	.0	.0	.1
21	118.3	.0	.0	17.0	.0	.0	67.6	211.6	279.1	227.4	23.8	.1	35.8	42.3	25.2	21.1	16.1	.0	.0	.0	.0
22	57.5	.0	.0	8.7	.1	.0	19.3	113.2	132.6	154.6	23.6	-11.6	29.5	37.8	24.2	20.4	13.4	.0	.0	.0	.0
24	119.3	.0	.0	31.4	1.8	.0	58.3	144.7	204.8	160.7	21.9	-6.8	38.6	51.7	32.8	25.8	14.2	.0	.0	.0	.1
25	190.7	.0	.0	16.2	8.6	.0	51.0	109.7	169.2	269.7	17.8	-10.3	29.8	35.9	25.1	18.0	7.0	.0	.0	.0	.0
26	586.1	270.1	103.7	18.3	.1	161.4	79.6	82.0	323.1	354.9	23.3	-13.7	52.6	54.8	32.0	20.6	5.7	.0	.0	.2	.2
27	127.9	6.3	8.6	66.6	4.8	-2.3	90.1	119.2	211.7	297.7	22.5	-9.8	33.1	46.8	31.6	22.4	6.5	.1	.1	.1	.2
28	514.7	184.9	.0	12.1	49.4	184.9	12.3	282.4	529.1	297.7	19.3	-12.6	23.2	36.3	31.2	35.8	9.4	.3	.8	.3	1.3
29	641.5	205.8	128.0	22.5	16.5	77.8	86.3	189.5	376.1	394.0	20.0	-21.0	37.9	55.4	34.2	29.9	5.8	.1	.2	.2	.0
30	715.0	278.9	225.9	39.6	18.2	53.0	127.3	141.3	339.8	424.6	21.0	-23.2	45.6	69.8	45.4	32.3	5.4	.2	.1	.3	.1
31	711.8	236.7	171.4	65.7	20.1	65.3	159.4	141.4	386.5	417.2	23.3	-20.2	52.0	74.5	43.6	33.8	6.3	.1	.1	.2	.1

TABLE 3

DAILY PERFORMANCE SUMMARY FOR FEBRUARY

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 2/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COOL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FR DAILY	HS	CL	WD STATUS
1	193.3	.0	.0	54.6	44.5	.0	155.8	138.9	339.1	349.7	20.0	-16.4	40.2	62.9	34.8	27.6	7.3	.1	.2	.6	.1
2	646.8	219.0	136.4	68.5	27.6	82.7	122.5	143.9	376.7	391.6	22.8	-16.9	42.5	64.0	43.6	36.4	8.4	.1	.1	.2	.1
3	39.4	.0	.0	60.3	15.7	.0	104.4	108.0	228.1	185.5	20.9	-8.1	33.8	62.0	35.5	30.4	7.7	.2	.1	.0	.2
4	590.3	197.5	-154.5	927.2	1737.5	352.0	-155.1	146.0	2080.4	218.6	22.0	-2.8	43.2	54.9	32.0	25.8	8.7	.7	.9	.4	.3
5	98.0	.0	.0	.0	81.0	.0	.0	206.1	287.1	169.7	19.9	1.4	20.8	30.7	24.5	23.6	9.7	.4	.5	.0	.0
6	151.3	.0	.0	18.0	18.6	.0	139.8	151.7	310.1	211.1	21.2	-.8	36.7	56.9	25.2	27.8	8.2	.1	.3	.0	.0
7	209.9	53.7	58.6	47.6	4.1	-4.9	151.0	89.4	239.6	217.1	21.9	-.8	43.5	67.3	34.6	28.2	6.9	.1	.0	.2	.1
8	360.2	87.5	51.9	.0	25.7	35.6	7.5	219.1	286.8	269.8	21.4	-6.7	25.9	34.0	31.1	35.6	5.9	.3	.3	.1	.0
9	207.8	55.6	34.4	.0	14.6	21.2	.0	225.4	261.2	163.0	20.8	3.8	19.5	26.4	24.8	31.1	9.4	.2	.4	.2	.0
10	250.4	66.8	39.3	.0	.2	27.5	.0	152.2	179.9	159.4	21.4	4.8	24.9	29.9	25.3	30.3	7.7	.3	.1	.2	.0
11	.0	.0	.0	.0	3.1	.0	.0	83.8	86.9	59.0	20.0	3.6	20.7	31.1	23.9	29.0	7.3	.7	.1	.0	.0
18	170.5	83.6	84.9	.0	.0	-1.3	.0	50.2	48.9	87.9	24.1	4.1	34.4	37.6	39.1	33.0	8.6	.0	.0	.4	.0
19	346.3	196.2	86.0	.0	17.7	110.2	.0	120.5	248.4	195.6	21.4	1.0	32.1	34.9	32.6	29.8	7.0	.1	.1	.3	.0
20	666.0	270.5	201.2	6.4	4.1	69.3	15.7	71.1	160.2	242.7	22.5	-2.8	39.9	43.9	42.7	36.3	4.9	.0	.0	.3	.0
21	186.5	.0	.0	56.7	7.8	.0	97.9	63.0	168.7	215.5	20.7	-1.8	37.9	51.1	36.8	28.8	4.7	.0	.0	.6	.1
22	536.0	165.7	110.1	13.2	9.8	55.6	77.2	111.3	254.0	298.6	22.2	-8.9	44.2	53.6	38.1	34.6	6.6	.1	.1	.2	.0
23	529.6	34.4	27.2	57.6	11.9	7.3	153.2	106.2	278.5	341.8	21.8	-13.8	49.4	64.9	36.9	30.1	4.2	.1	.0	.1	.1
24	531.7	189.9	127.9	71.3	14.3	62.1	98.6	64.5	237.5	252.8	21.5	-4.8	42.9	57.8	44.7	38.5	5.9	.0	.1	.2	.1
25	473.1	15.4	6.9	.0	12.6	8.5	39.4	84.6	145.1	188.4	22.5	2.8	42.3	39.8	31.5	27.2	6.1	.0	.0	.0	.0
26	352.7	23.8	13.0	14.4	13.3	12.7	12.0	119.6	157.6	167.6	20.5	3.0	29.9	31.7	26.4	27.2	7.3	.3	.1	.1	.0
27	605.3	237.5	166.3	18.8	.0	71.3	89.5	70.5	231.2	219.1	24.4	1.7	50.0	61.0	41.9	33.9	7.7	.0	.0	.3	.0
28	104.4	.0	.0	48.4	11.9	.0	113.4	94.9	220.1	214.1	22.4	.1	37.1	53.6	35.9	30.8	6.9	.1	.1	.6	.1

TABLE 4

DAILY PERFORMANCE SUMMARY FOR MARCH

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 3/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FF DAILY	HS	CL	WD STATUS
1	185.4	.0	.0	9.4	12.4	.0	53.9	148.0	214.3	248.4	21.4	-4.5	30.3	39.6	27.4	29.3	7.3	.1	.2	.0	.0
2	644.7	247.1	163.2	.0	3.5	83.9	.0	175.1	262.5	254.7	21.5	-5.2	33.3	35.9	35.5	34.4	6.3	.1	.1	.3	.0
3	725.7	277.6	182.8	.0	22.0	94.8	.0	101.8	218.6	301.5	22.4	-9.0	37.5	42.5	43.7	39.0	5.4	.0	.1	.3	.0
4	204.6	.0	.0	.0	29.5	.0	.0	117.8	147.3	218.5	20.3	-2.5	23.9	28.9	29.9	28.6	5.7	.3	.1	.0	.0
5	149.2	20.9	13.2	.0	2.4	7.7	.0	145.4	155.5	136.9	19.1	4.8	19.4	22.0	22.0	24.3	7.2	.1	.1	.2	.0
6	128.9	.0	.0	8.9	.1	.0	73.5	121.1	194.7	140.0	21.4	6.9	32.5	43.9	22.7	23.0	7.4	.1	.1	.2	.0
7	126.8	13.1	5.5	.0	-2.8	7.5	.0	118.4	123.2	137.6	20.2	5.9	23.1	25.0	20.1	23.5	7.3	.1	.1	.2	.0
8	436.9	146.4	93.4	.0	-2.3	53.0	.0	152.2	202.9	191.8	20.7	.7	31.4	35.1	28.7	28.6	6.7	.3	.1	.2	.0
9	75.7	8.6	3.9	2.5	7.5	4.7	8.9	56.6	77.7	103.2	18.5	-3.0	23.7	32.8	29.2	28.3	5.1	.1	.1	.6	.0
10	42.6	.0	.0	.0	.0	.0	2.3	13.4	15.7	63.0	24.8	2.3	31.7	32.0	32.7	26.2	6.8	.0	.0	.0	.0
11	276.0	28.7	19.6	.0	5.0	9.1	.0	175.3	189.3	186.8	20.8	1.4	25.7	25.4	24.9	28.4	5.9	.1	.1	.1	.0
20	564.8	219.4	153.0	.0	5.9	66.5	.0	113.1	185.5	197.2	19.6	-.9	30.4	32.0	31.8	31.6	5.3	.1	.1	.3	.0
21	533.9	201.7	150.4	.0	10.3	51.3	2.7	91.3	155.5	204.9	21.5	.2	34.0	38.1	37.3	33.9	5.2	.1	.1	.3	.0
22	228.0	.0	.0	.0	21.9	.0	.0	83.5	105.4	193.2	21.7	2.6	26.6	28.0	28.4	27.3	6.8	.0	.1	.0	.0
23	402.8	.0	.0	.0	3.6	.0	.0	119.6	123.2	170.6	20.6	2.9	29.4	23.3	19.5	21.4	4.2	.1	.1	.6	.0
24	525.3	32.3	17.9	.0	-1.2	14.4	3.1	119.8	136.0	152.3	22.1	6.2	33.7	27.0	22.9	24.5	6.9	.1	.1	.0	.0
25	179.0	.0	.0	.0	-5.9	.0	.0	140.6	134.7	197.2	20.4	-.2	19.8	21.3	19.0	24.8	6.6	.1	.1	.0	.0
26	234.4	7.0	3.1	.0	-4.2	3.9	.0	174.0	173.7	195.8	18.7	-1.7	19.2	20.5	19.4	24.9	6.3	.1	.2	.6	.0
27	124.7	.0	.0	.0	-8.2	.0	.0	247.3	239.1	218.3	19.5	-3.3	17.1	20.4	19.1	28.0	7.0	.2	.2	.6	.0
28	390.0	86.9	54.0	.0	-.9	32.9	.0	130.8	162.7	199.9	19.9	-1.0	25.2	25.7	24.5	27.3	5.8	.1	.1	.2	.0
29	158.8	10.4	6.1	.0	1.9	4.3	.0	89.0	95.2	150.5	18.3	2.7	20.1	21.1	21.8	22.6	6.2	.1	.1	.1	.0
30	6.4	.0	.0	.0	1.2	.0	.0	80.3	81.5	60.8	15.1	-1.8	12.8	17.2	18.8	23.6	4.2	.2	.2	.0	.0

TABLE 5

DAILY PERFORMANCE SUMMARY FOR APRIL

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 4/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TC HOUSE (C)	CRAWL SPACE (C)	FR DAILY	HS	CL	WD STATUS
14	116.2	76.1	75.2	.0	.0	.9	.0	38.6	39.5	69.3	24.5	10.3	34.0	34.0	32.8	28.9	11.0	.0	.0	.5	.0
15	163.0	75.6	63.6	.0	6.4	12.0	.0	70.3	88.6	94.8	20.8	6.6	27.3	29.7	30.4	28.5	9.8	.1	.1	.2	.0
16	200.3	66.3	60.7	.0	.0	5.6	.0	52.4	58.0	41.6	23.3	15.8	30.1	29.1	28.6	28.5	12.6	.0	.0	.6	.0
17	312.2	102.8	92.5	.0	.0	10.3	.0	50.8	61.2	79.0	22.2	13.9	28.6	28.9	29.7	28.5	12.6	.0	.0	.3	.0
18	180.1	61.0	55.0	.0	12.6	6.0	.0	109.3	126.9	147.9	20.4	5.0	23.7	27.8	29.2	28.1	11.2	.1	.1	.2	.0
19	337.8	95.1	81.1	.0	14.9	14.0	.0	117.8	145.7	174.3	21.7	3.5	27.7	29.4	30.1	29.6	10.2	.1	.1	.2	.0
20	149.2	106.9	88.4	.0	19.1	18.5	.0	138.5	176.1	153.2	19.4	3.5	24.8	28.9	29.8	29.7	9.0	.2	.2	.2	.0
21	154.5	156.1	145.9	.0	3.9	10.2	.0	88.6	102.7	143.6	20.5	5.5	28.7	30.1	30.3	28.5	9.3	.0	.0	.4	.0
22	257.9	93.7	95.0	.0	12.3	3.6	2.8	114.7	133.4	135.9	21.2	7.0	28.0	30.8	31.6	28.6	10.6	.1	.1	.2	.0
23	46.9	.0	.0	.0	24.1	.0	.0	69.3	93.4	142.5	17.6	2.9	18.5	24.3	27.6	24.6	10.0	.1	.1	.0	.0
24	182.2	.0	.0	.0	7.7	.0	.0	152.9	160.7	173.9	21.3	3.2	24.8	23.2	20.3	23.4	9.5	.2	.2	.0	.0
25	183.6	.0	.0	.0	-7.3	.0	.0	141.7	134.4	118.7	17.5	5.1	20.4	18.8	17.8	21.8	9.8	.2	.2	.0	.0
26	3.2	.0	.0	.0	.1	.0	.0	12.6	12.7	41.9	17.4	4.3	15.9	18.6	17.6	17.6	7.3	.0	.0	.0	.0

TABLE 6

DAILY PERFORMANCE SUMMARY FOR MAY

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 5/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STOPE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	CALL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TC HOUSE (C)	CRAWL SPACE (C)	FR DAILY	HG	CL STATUS	LD
5	6.4	.0	.1	.0	.0	-.0	.0	6.4	6.4	21.4	21.4	12.4	21.4	23.4	24.2	23.1	12.4	.0	.6	.6	.0
6	154.5	20.8	31.5	4.1	9.7	-10.7	18.7	95.1	112.9	149.7	20.4	4.8	24.3	31.4	26.4	25.9	10.2	.1	.1	.1	.0
7	318.6	122.2	108.6	.0	4.5	13.7	.0	73.7	91.8	128.5	19.0	5.6	25.7	27.3	27.9	24.8	8.2	.0	.6	.3	.0
8	142.8	25.8	26.2	.0	12.4	-.4	.0	111.8	123.8	135.5	16.9	2.8	16.9	22.5	24.5	23.8	8.9	.1	.1	.2	.0
9	239.8	63.9	56.3	.0	12.6	7.6	.0	100.7	120.8	141.5	19.4	3.7	20.9	24.4	25.2	25.9	9.6	.2	.2	.2	.0
10	276.0	98.5	87.8	.0	5.1	10.7	.0	93.9	109.8	136.8	20.0	5.7	24.6	26.5	26.8	25.6	9.5	.1	.1	.3	.0
11	234.4	67.4	59.0	.0	4.7	8.4	.0	73.0	86.1	115.0	20.4	8.4	24.8	26.3	27.2	25.6	10.7	.1	.1	.3	.0
12	247.2	91.3	81.8	.0	3.6	9.5	.0	86.7	99.8	97.7	20.6	10.5	26.0	27.3	28.1	24.1	10.7	.0	.6	.3	.0
13	190.7	54.6	50.4	.0	8.9	4.2	.0	139.8	152.9	91.8	22.1	12.5	25.5	27.1	27.7	27.7	13.1	.1	.1	.3	.0
14	252.5	101.9	98.8	.0	2.2	3.1	.0	63.1	68.4	68.7	20.3	13.1	26.7	27.4	28.1	25.8	12.3	.0	.0	.4	.0
15	256.8	113.7	103.4	.0	5.0	10.3	.0	76.6	91.8	53.6	22.5	16.9	29.4	30.2	31.2	29.1	15.1	.0	.0	.4	.0
16	106.6	32.7	28.5	.0	2.5	4.2	.0	34.1	40.7	25.9	22.3	17.6	26.8	27.6	29.3	26.8	14.7	.0	.0	.2	.0
20	224.8	121.7	117.7	.0	.0	3.9	.0	53.1	57.0	28.3	24.5	19.0	37.1	35.6	35.3	33.2	14.8	.0	.0	.8	.0
21	245.1	103.5	103.4	.0	.0	8.0	.0	65.6	73.6	57.5	23.2	17.2	30.8	31.0	32.5	29.2	15.2	.0	.0	.4	.0
22	234.4	108.9	104.6	.0	.0	4.3	.0	78.6	82.9	49.1	22.4	17.3	30.7	30.8	32.8	29.8	15.8	.0	.0	.4	.0
23	216.3	95.5	92.9	.0	.0	2.6	.0	55.8	58.4	43.2	22.8	19.1	30.5	30.9	32.8	29.3	15.5	.0	.0	.4	.0
24	164.1	.0	.0	.0	.0	.0	.0	41.1	41.1	70.5	23.3	15.9	27.8	28.2	29.1	25.3	15.6	.0	.0	.0	.0
25	213.1	105.8	104.8	.0	.0	1.0	2.2	64.1	67.2	51.7	21.6	14.2	30.3	30.9	31.4	28.1	15.5	.0	.0	.4	.0
26	213.1	114.8	103.9	.0	.0	8.8	.0	78.4	87.2	32.1	23.6	20.3	31.9	31.9	33.4	30.2	17.2	.0	.0	.4	.0
27	63.9	20.3	18.4	.0	.0	1.9	.0	17.5	19.3	23.0	22.3	17.5	27.8	28.7	32.2	27.2	16.3	.0	.0	.1	.0

TABLE 7

DAILY PERFORMANCE SUMMARY FOR JULY

PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 7/79

DAY	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FR DAILY	HS	CL	WD STATUS
15	59.7	25.6	39.1	.0	.0	-13.6	.0	25.7	12.2	7.3	24.3	22.0	31.7	31.2	31.4	30.6	20.8	.0	.0	.9	.0
16	199.3	107.1	105.8	.0	.0	1.3	.0	66.4	67.7	38.3	24.3	20.4	32.0	31.7	33.1	30.2	20.0	.0	.0	.4	.0
17	215.3	121.0	116.2	.0	.0	4.8	.0	51.4	56.3	18.6	25.1	23.2	35.2	34.8	37.1	33.3	21.0	.0	.0	.4	.0
18	215.3	117.0	114.1	.0	.0	2.9	.0	73.0	75.9	19.8	27.0	25.0	36.7	36.2	38.3	34.7	22.5	.0	.0	.5	.0
19	220.6	112.8	114.5	.0	.0	-1.7	.0	63.3	61.6	16.9	26.8	25.1	36.9	36.4	38.3	35.1	23.5	.0	.0	.5	.0
20	219.5	61.2	60.3	.0	.0	.9	.0	58.4	59.3	21.1	26.1	23.9	36.0	33.6	34.3	32.7	22.4	.0	.0	.3	.0
21	225.9	119.4	118.3	.0	.0	1.1	.0	85.2	86.4	12.4	26.8	25.5	36.9	36.3	38.2	35.0	23.5	.0	.0	.5	.0
22	94.8	16.8	26.6	.0	.0	-9.8	.0	63.7	53.9	52.7	25.1	19.6	29.8	30.7	33.8	30.2	21.9	.0	.0	.2	.0
23	221.6	10.6	15.2	.0	.0	-4.7	.0	61.8	57.2	26.4	23.8	21.1	35.6	29.1	31.9	27.6	20.3	.0	.0	.1	.0
24	246.2	119.3	114.3	.0	.0	5.1	.0	65.8	70.8	24.0	25.2	22.7	34.4	33.9	35.6	32.4	21.5	.0	.0	.4	.0
25	257.9	50.0	52.6	.0	.0	-2.6	.0	64.0	61.4	41.2	24.9	20.6	36.0	32.0	35.1	30.7	21.1	.0	.0	.3	.0
26	252.5	60.2	54.4	.0	.0	5.8	.0	64.2	70.0	43.8	24.8	20.2	35.6	31.8	34.7	30.6	20.9	.0	.0	.3	.0
27	200.3	31.7	35.6	.0	.0	-3.8	.0	62.7	58.8	30.3	23.6	20.4	34.0	30.2	33.3	29.1	20.9	.0	.0	.3	.0
28	136.4	.0	.0	.0	.0	.0	.0	30.1	30.1	18.6	22.6	19.7	32.8	26.7	29.9	25.7	19.3	.0	.0	.0	.0

TABLE 8: OVERALL PERFORMANCE SUMMARY

Month	Solar Inso MJ	Solar Output MJ	Coll. Fan MJ	Solar Store MJ	Wood Store MJ	Store House MJ	Solar House MJ	Wood House MJ	Elect. House MJ	Total Input MJ	Calcu. Load MJ	House Temp. °C	Amb. Temp. °C	Data Days
Jan.	8192	1624	82	975	495	129	647	1670	4603	7048	7525	22.2	-12.3	24
Feb.	6649	1703	97	1143	528	321	558	1370	2468	4731	4582	21.7	- 2.9	20
March	6263	1290	69	866	18	95	432	133	2640	3297	3745	21.3	0.0	19
April	2290	839	96	758	0	94	81	3	1158	1322	1462	20.9	6.9	12
May	3864	1450	203	1359	4	72	89	20	1382	1561	1476	21.3	12.6	18
July	2766	927	142	927	0	0	0	0	809	809	364	25.1	22.1	13

NOTE: Each entry in this table represents the average of about 250,000 data system readings.

TABLE 9: SOLAR SYSTEM PERFORMANCE FACTORS

Month	① Net Collector Efficiency	② Solar System Efficiency	③ Storage Efficiency
Jan.	18.8	45.1	9
Feb.	24.2	45.6	19.2
March	19.5	40.5	10.7
April	32.4	20.8	12.4
May	32.2	11.1	5.2
July	28.4	0	0

① $\frac{\text{Monthly collector output - fan power}}{\text{Monthly solar insolation}}$

② $\frac{\text{Solar heat delivered to house}}{\text{Collector output}}$

③ $\frac{\text{Storage output}}{\text{Storage input}}$

TABLE 10: DISTRIBUTION OF HEAT

Month	Days	Total		*Solar		*Wood		Electric	
		MJ	%	MJ	%	MJ	%	MJ	%
Jan.	24	7048	100	733	11	1713	24	4603	65
Feb.	20	4731	100	778	17	1471	31	2468	52
March	19	3297	100	525	16	135	4	2640	80
April	12	1322	100	175	13	3	0	1158	87
May	18	1561	100	161	10	20	1	1382	89
July	13	809	100	0	0	0	0	809	100

*Direct + Stored

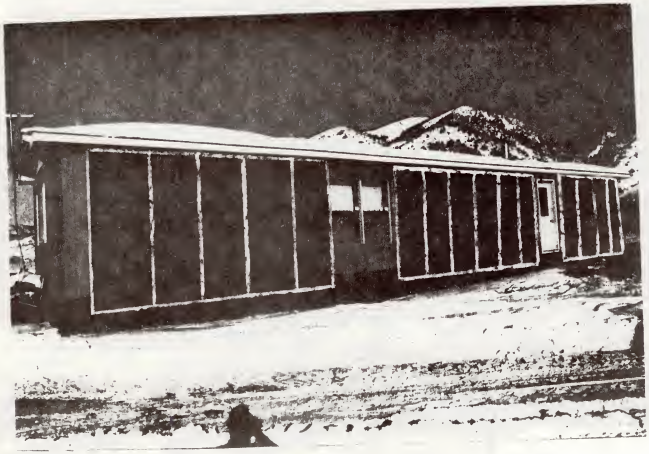


FIGURE 1: SOLAR/WOOD-HEATED MOBILE HOME RESEARCH SITE

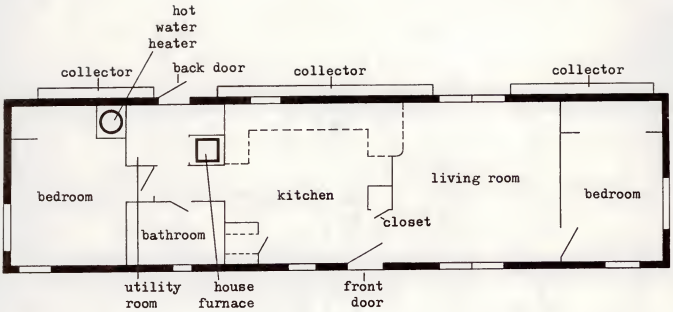


FIGURE 2: MOBILE HOME FLOOR PLAN

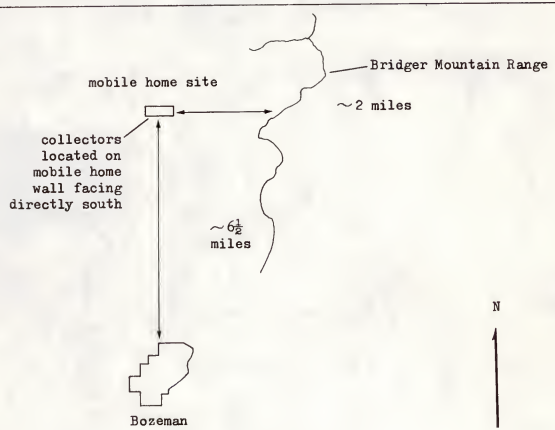


FIGURE 3: MOBILE HOME SITE LOCATION

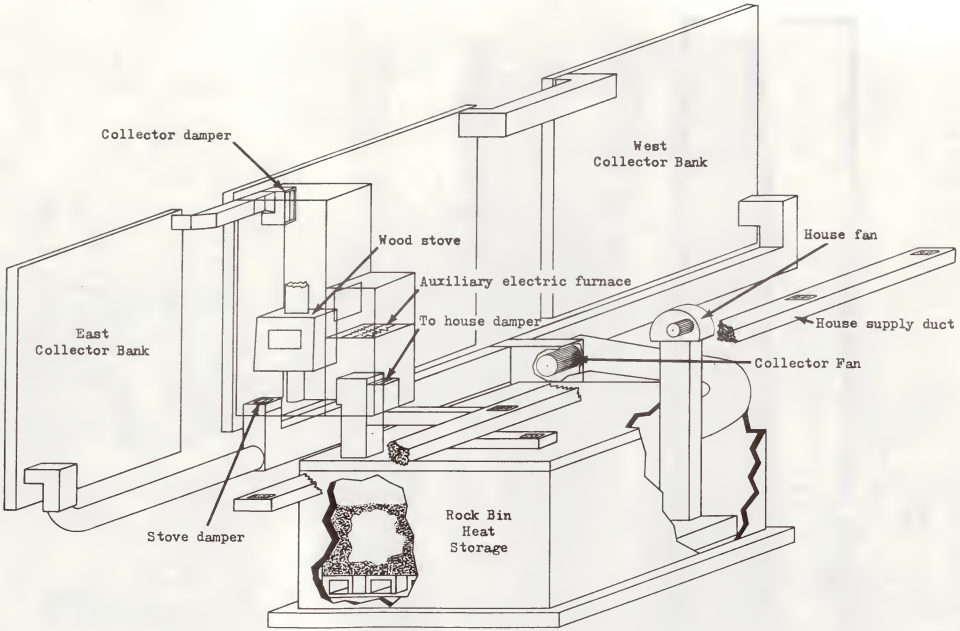


FIGURE 4: MOBILE HOME DUCTING FOR SOLAR/WOOD/ELECTRIC HEATING SYSTEM

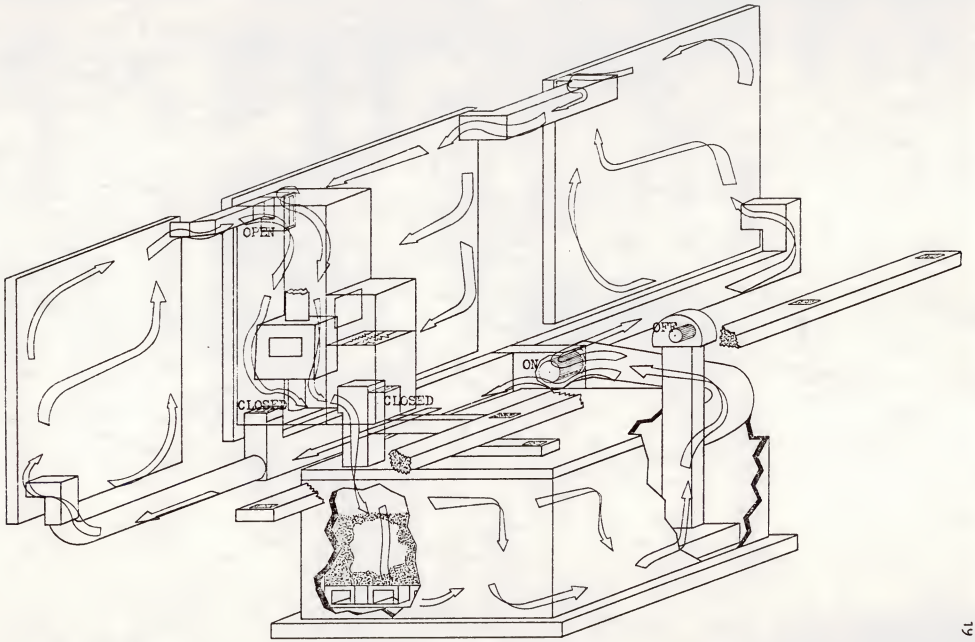


FIGURE 5: SOLAR HEAT TO STORAGE

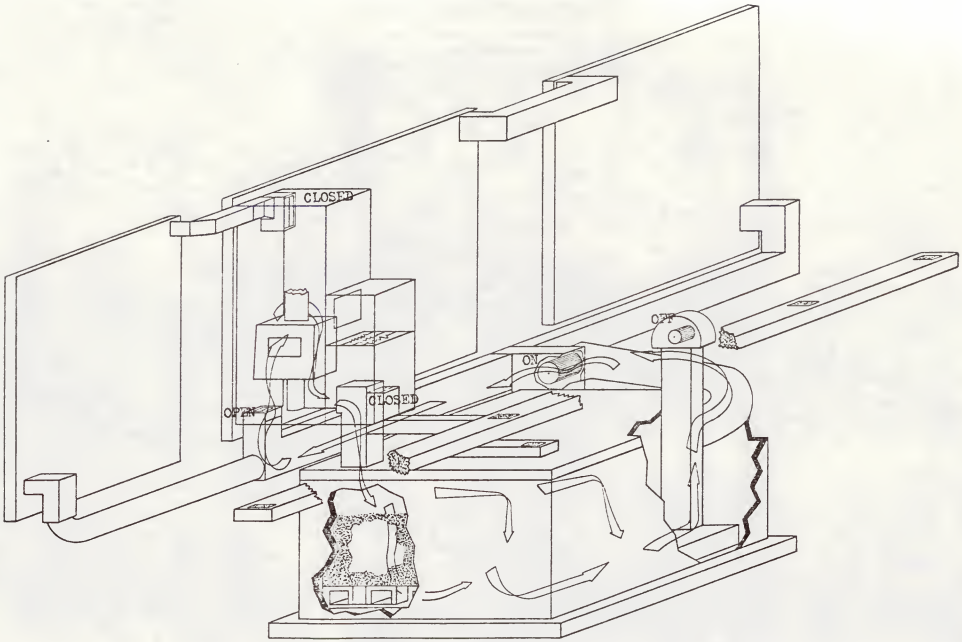


FIGURE 6: WOOD HEAT TO STORAGE

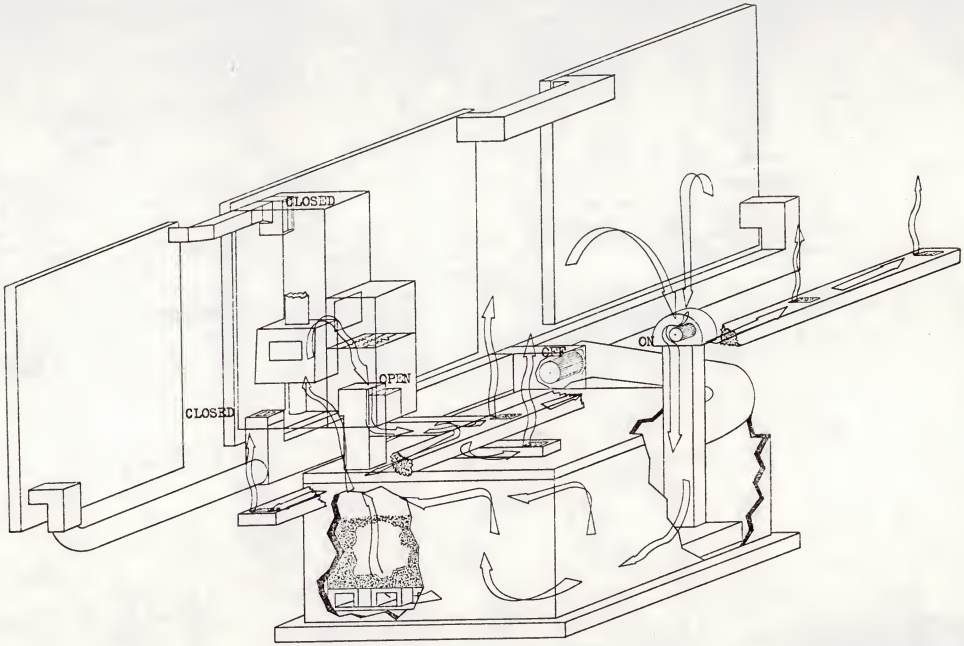
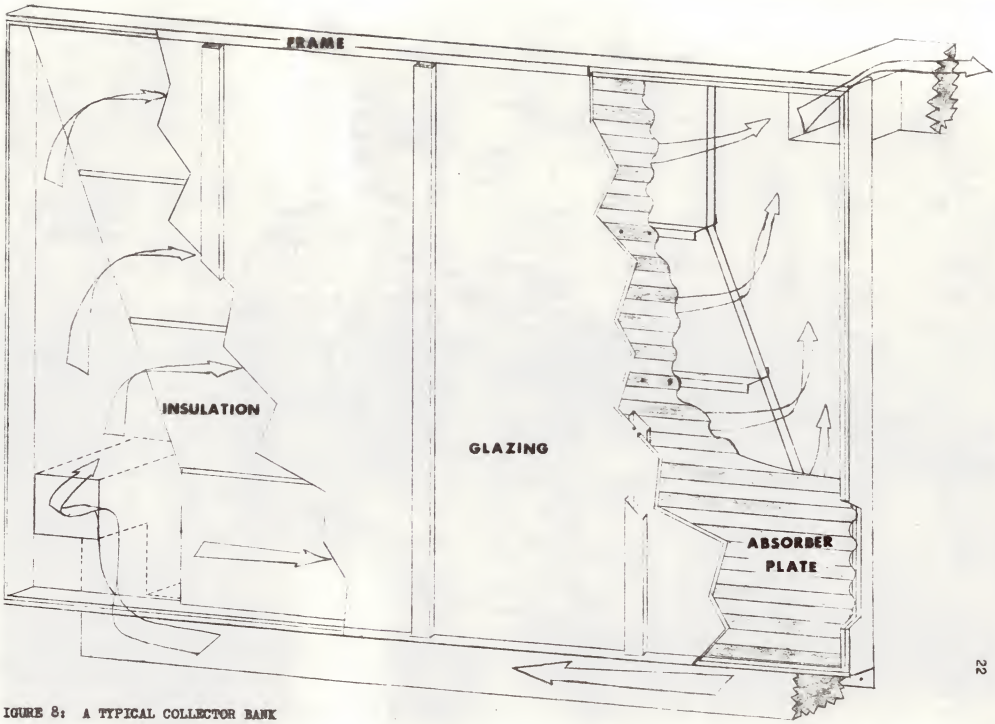
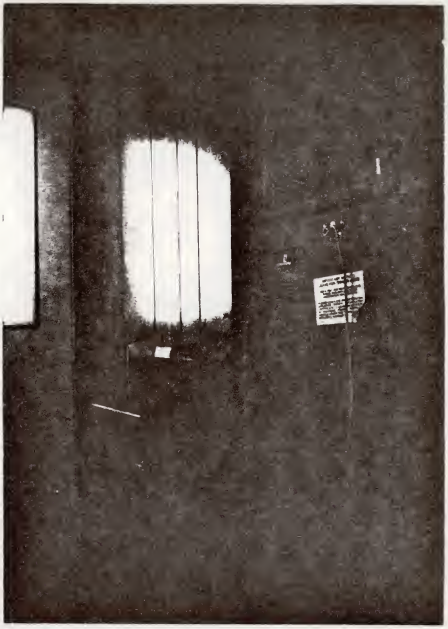


FIGURE 7: STORED HEAT AND AUXILIARY HEAT TO HOUSE



IGURE 8: A TYPICAL COLLECTOR BANK

(a) Plenum cover removed



(b) Plenum cover in place

FIGURE 9: PLENUM CHAMBER WITH SMALL WOOD STOVE

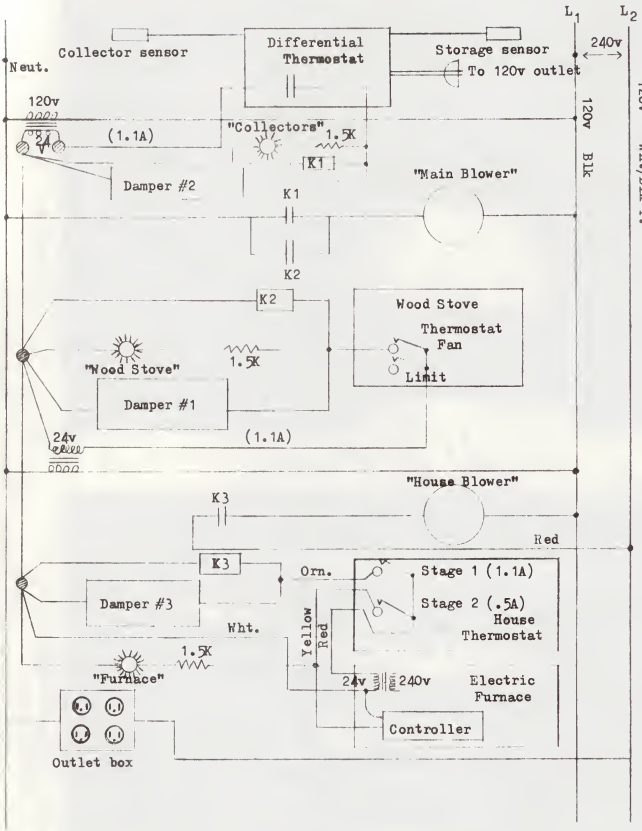


FIGURE 10: CONTROL WIRING SCHEMATIC - SOLAR MOBILE HOME

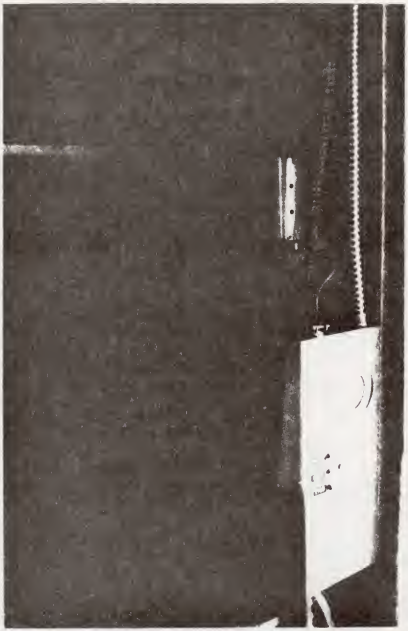
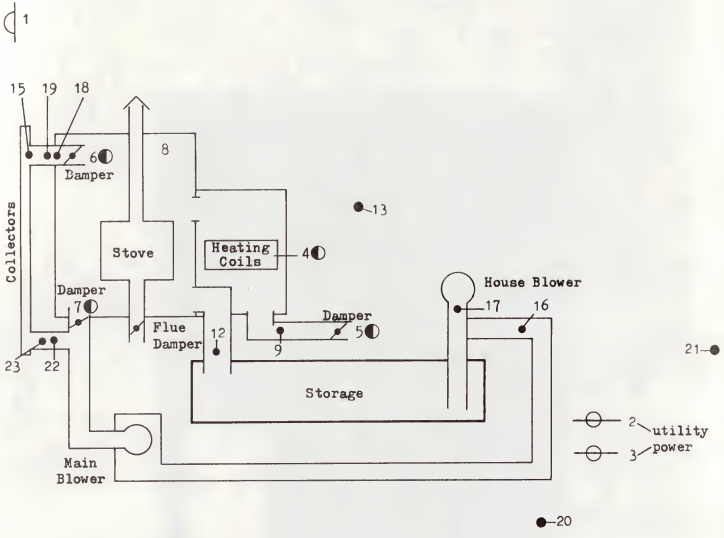


FIGURE 11
CONTROL SYSTEM: DIFFERENTIAL THERMOSTAT, STOVE THERMOSTAT,
CONTROL 24-VOLT RELAYS AND STATUS LIGHTS



1 - Solar Insolation
2 - Utility Power
3 - Utility Power
4 - Heating Coils
5 - House Damper Status
6 - Collector Damper Status
7 - Stove Damper Status
8 - Plenum Air
9 - Main House Heat Duct (average of 3 probes)
12 - Storage to Plenum Duct (average of 3 probes)
13 - House Temperature
15 - West Collectors Outlet
16 - Inlet to Main Blower
17 - Outlet from House Blower
18 - East Collector Outlet
19 - Between West Collectors (in living room duct over window)
20 - Crawl Space
21 - Ambient Temperatures
22 - East Collector Inlet
23 - West Collectors Inlet

FIGURE 12: INSTRUMENTATION SCHEMATIC FOR SOLAR MOBILE HOME

FIGURE 13:
DATA ACQUISITION SYSTEM (top to bottom):
VIDEO DISPLAY, KEYBOARD AND COMPUTER, ANALOG/DIGITAL/CLOCK INTERFACE AND TAPE RECORDER, BATTERY AND POWER SUPPLY

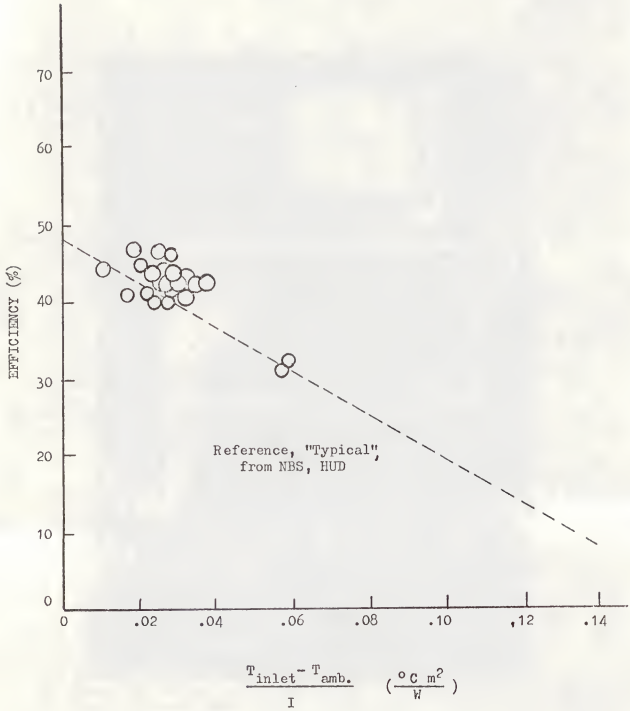


FIGURE 14: MOBILE HOME COLLECTOR EFFICIENCY CURVE

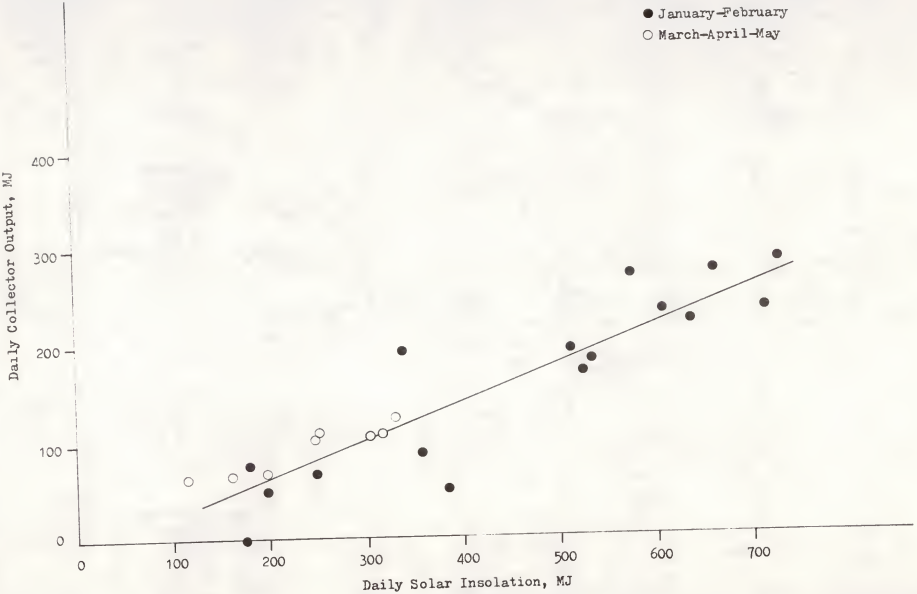


FIGURE 15: COLLECTOR OUTPUT

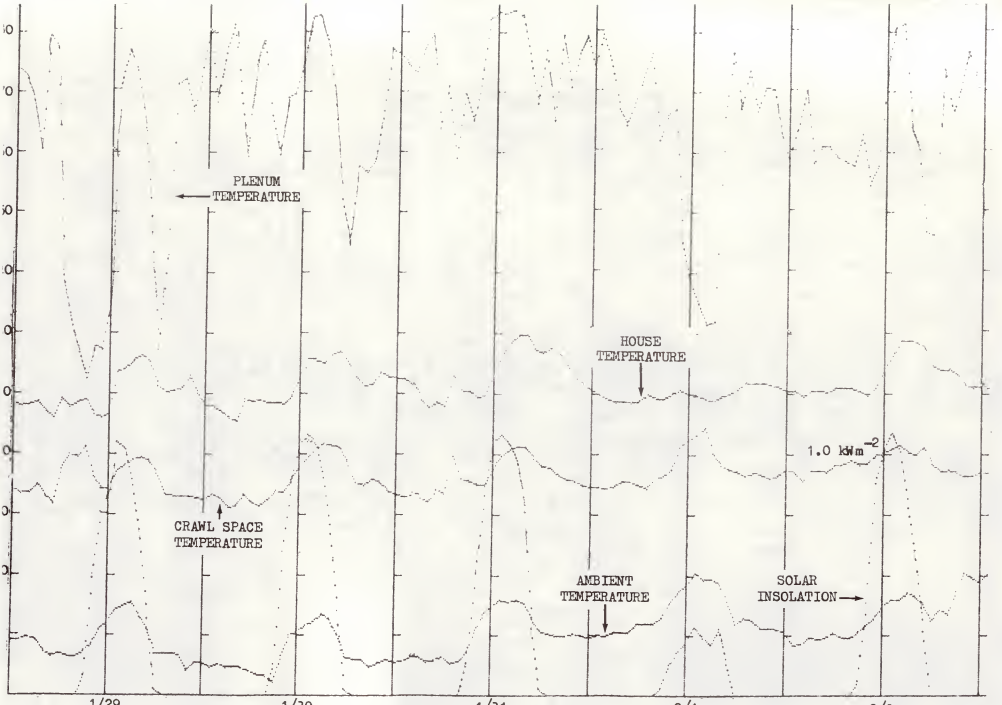


FIGURE 16: GRAPH OF 5 DAYS OF DATA IN JANUARY

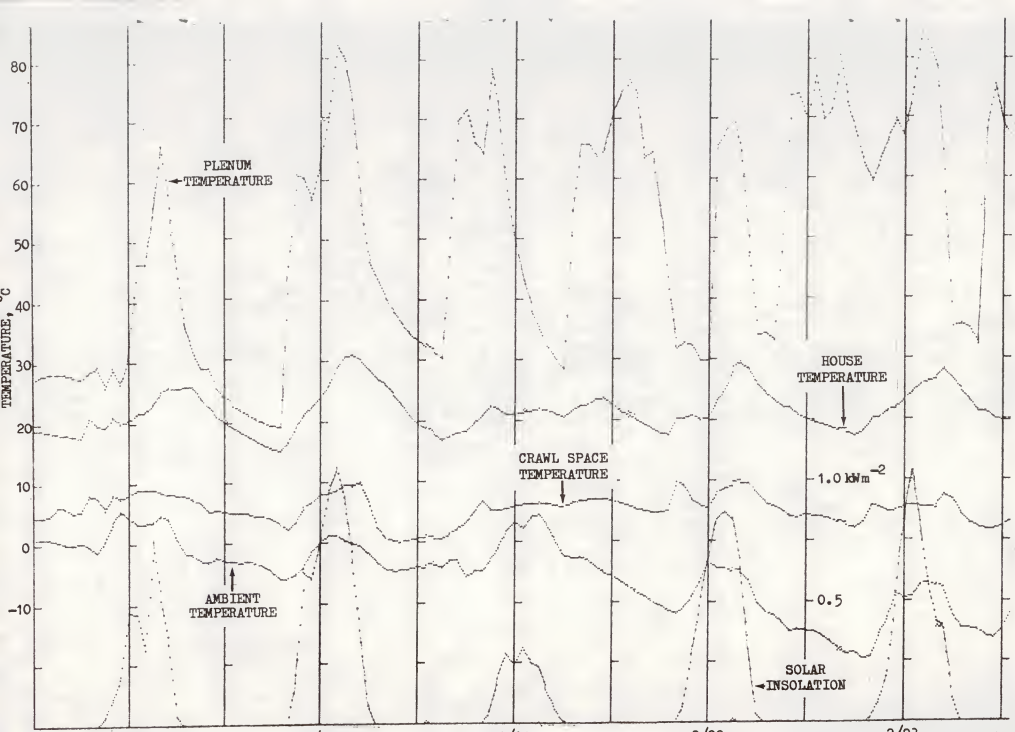


FIGURE 17: GRAPH OF 5 DAYS DATA IN FEBRUARY

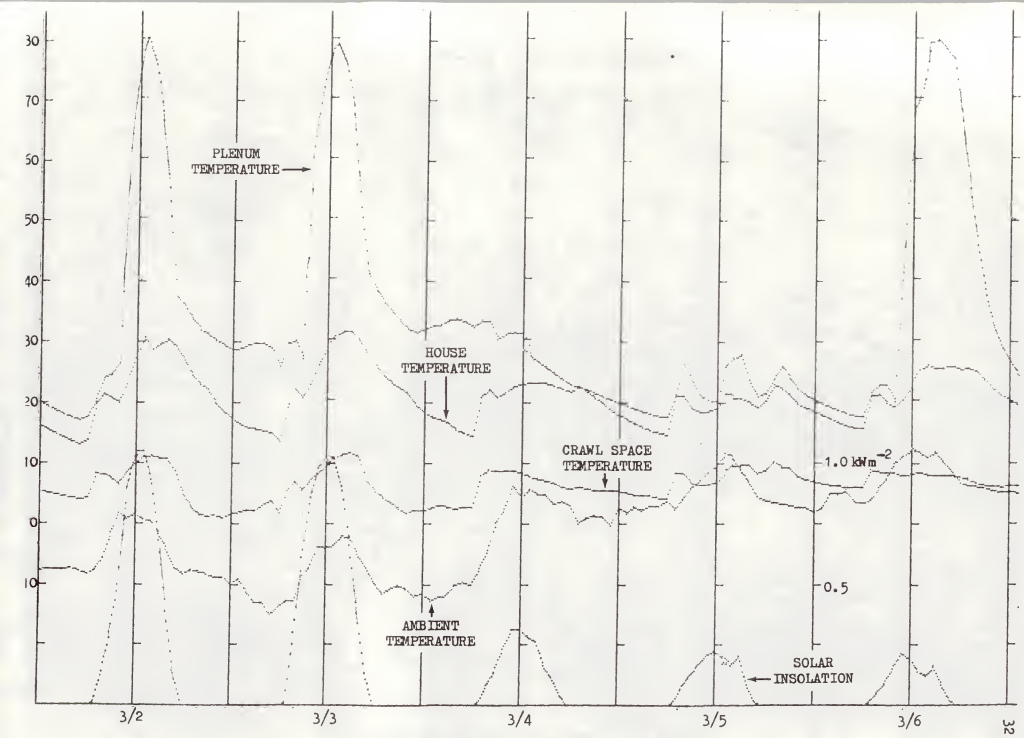


FIGURE 18: GRAPH OF 5 DAYS DATA IN MARCH

APPENDIX I

MASS FLOW DATA

APPENDIX I - Mass Flow Data

Technique

Mass flow rates were obtained for all operational modes of the system. The automatic control system was manually over-ridden to artificially achieve each mode for mass flow measurement purposes.

Mass flow data were obtained using a hot-wire anemometer probe. The probe automatically compensates for temperature effects to give a mass flow rate(in standard cubic meters/second/square meter of flow area). Holes were drilled in ducts to permit access to the flows. Each hole was taped shut, and the tape was removed from a hole only when the probe was being used in that particular hole. This taping procedure was followed to prevent duct leaks which would have caused erroneous data.

The probe was read at a number of insertion depths for each hole to obtain flow profiles across each duct. Each duct cross-section has either two or three holes to permit acquisition of an equal number of profiles at the cross-section. All profile measurements were repeated to insure that the data were reproducible.

Four locations in the duct system were chosen for flow profile measurement. The locations were limited to relatively long straight duct sections to insure that the best possible accuracy would result. Figure AI-1 shows the four locations. With flow rates known at the four indicated locations, flow rates at all other locations could be inferred (assuming negligible leakage from the system).

Experimental Results

Raw data were plotted so that the flow profiles could be sketched. The duct profiles for all operational modes are shown in Figures AI-2 through AI-8. (Flow profiles in the blower duct were very nearly constant and are not shown in the Figures.) Average velocities were obtained from those plots, and were converted to mass flow rates (standard cubic meters/second) by multiplication by the corresponding duct areas. Those rates are indicated on the diagrams at the bottoms of the Figures. Inferred flow rates are shown in parentheses.

Error Estimations

Errors obtaining from the finite accuracy of the anemometer are believed to be negligible. A major source of error is time fluctuations in flow rate which are caused by line voltage fluctuations to the motor driven blowers, vibrations, and bearing lubrication efficiency fluctuations. Flow measurements were repeated. This repetition process led to the conclusion that time fluctuations introduced errors of about ten percent. The meter sensitivity at the low velocities limited the raw data accuracy to about five percent. Flow measurements were obtained in the short duct connecting the plenum chamber and storage box. Measurements from such a short duct are not reliable data. These measurements were compared with measurements from other parts of the system as an indication of the system leakage. It was concluded that leakage introduced errors of about ten percent. Accounting for all the error sources led to the conclusion that the flow data overall errors are less than twenty percent.

Flow Balance Assumptions

For computational purposes it was assumed that there were no system leaks. The system was carefully checked for leaks and the major leaks found were sealed with caulking or stuffed with fiber insulation. An air system, however, is inherently leaky. The four measurement points were chosen to give information on useful energy flows. Collector flows were measured at the outlets of the east and west collector banks. Thus, energy delivered by the collectors was obtained. Using collector inlet flow rates in energy calculations would have resulted in inflated values of efficiencies because energy lost due to collector leaks would have been counted as part of the energy supplied by the collectors.

Heat delivered to living space was characterized by the mass flow of air in the main duct. Any energy lost from the plenum is thereby not included as useful heat in the computations. It would not have been appropriate to characterize this flow as the flow delivered by the house blower because house blower flow would include flow due to air infiltration into the living space.

The calculation methods employed do not explicitly account for system

leakage. But system leakage was implicitly accounted for by the methods because only useful delivered energies were computed.

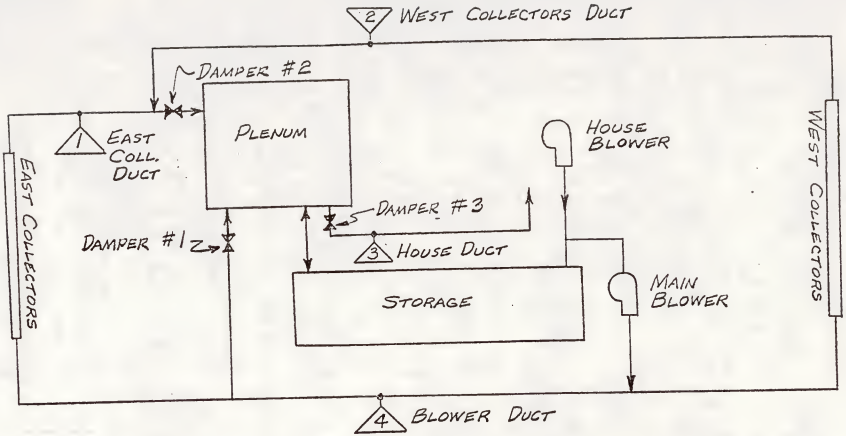
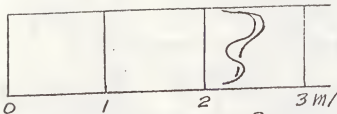


FIGURE AI - 1 FLOW MEASUREMENT LOCATIONS

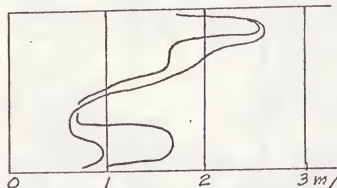


1. EAST COLLECTORS DUCT

Avg $V = 2.40$ m/s

$A = 0.0271$ m^2

$\dot{m} = 0.065$ m^3/s

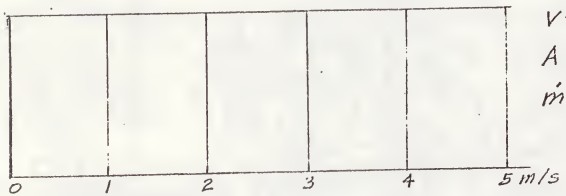


2. WEST COLLECTORS DUCT

$V = 1.41$ m/s

$A = 0.0774$ m^2

$\dot{m} = 0.110$ m^3/s



3. HOUSE DUCT

$V = 0.0$ m/s

$A = 0.0734$ m^2

$\dot{m} = 0.0$ m^3/s

4. BLOWER DUCT; $V = 1.28$ m/s, $A = 0.0903$ m^2; $\dot{m} = 0.116$ m^3/s

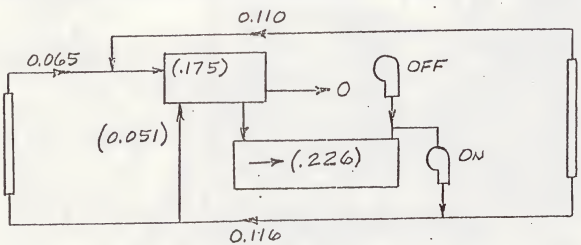
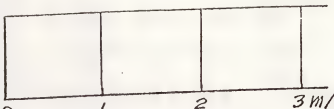


FIGURE AT-2 MODE # 1 SOLAR HEAT TO STORAGE

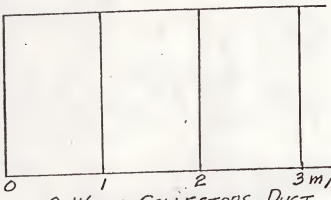


1. EAST COLLECTORS DUCT

Avg $V = 0.0$ m/s

$A = 0.0271$ m²

$\dot{m} = 0.0$ m³/s

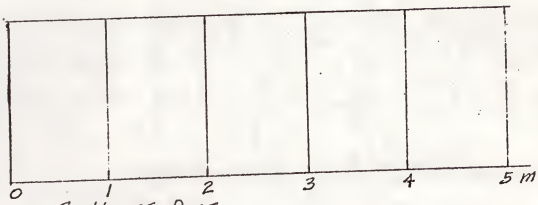


2. WEST COLLECTORS DUCT

$V = 0.0$ m/s

$A = 0.0774$ m²

$\dot{m} = 0.0$ m³/s



3. HOUSE DUCT

$V = 0.0$ m/s

$A = 0.0734$ m²

$\dot{m} = 0.0$ m³/s

4. BLOWER DUCT: $V = 3.47$ m/s, $A = 0.0903$ m², $\dot{m} = 0.313$ m³/s

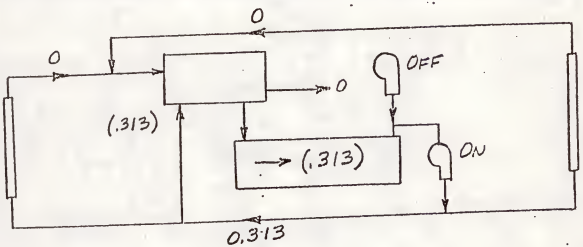
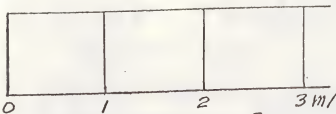
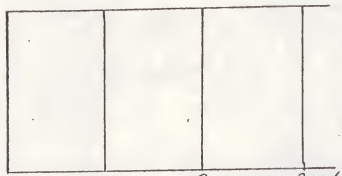


FIGURE AI-3 MODE # 2 WOOD HEAT TO STORAGE



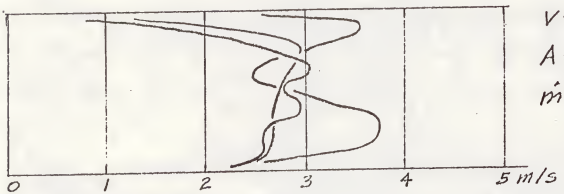
1. EAST COLLECTORS DUCT

Avg $V = 0.0$ m/s
$A = 0.0271$ m²
$\dot{m} = 0.0$ m³/s



2. WEST COLLECTORS DUCT

$V = 0.0$ m/s
$A = 0.0774$ m²
$\dot{m} = 0.0$ m³/s



3. HOUSE DUCT

$V = 2.86$ m/s
$A = 0.0734$ m²
$\dot{m} = 0.210$ m³/s

4. BLOWER DUCT: $V = 0$ m/s, $A = 0.0903$ m²; $\dot{m} = 0.00$ m³/s

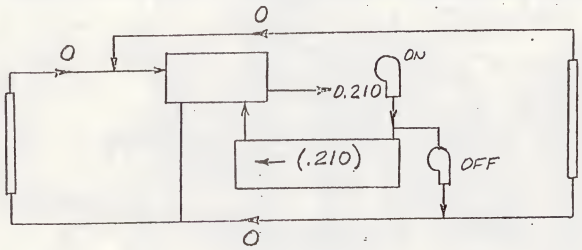
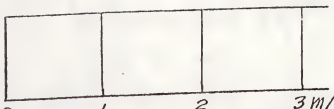


FIGURE A1-4 MODE #3 STORAGE HEAT TO HOUSE

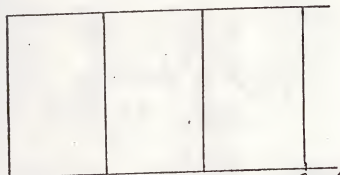


1. EAST COLLECTORS DUCT

Avg $V = 0.0$ m/s

$A = 0.0271$ m^2

$\dot{m} = 0.0$ m^3/s

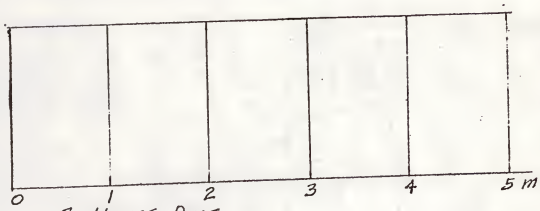


2. WEST COLLECTORS DUCT

$V = 0.0$ m/s

$A = 0.0774$ m^2

$\dot{m} = 0.0$ m^3/s



3. HOUSE DUCT

$V = 0.0$ m/s

$A = 0.0734$ m^2

$\dot{m} = 0.0$ m^3/s

4. BLOWER DUCT: $V = 3.47$ m/s, $A = 0.0903$ m^2; $\dot{m} = 0.313$ m^3/s

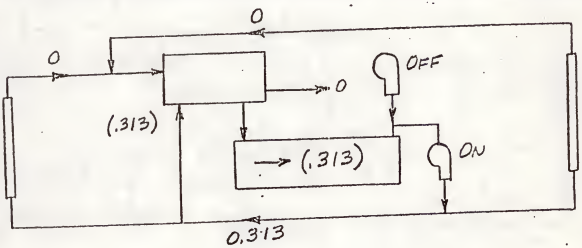
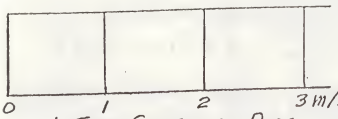
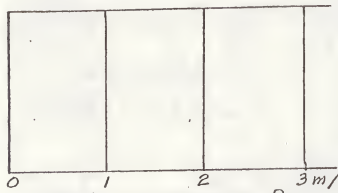


FIGURE AI-3 MODE # 2 WOOD HEAT TO STORAGE



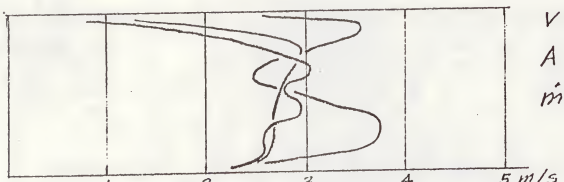
1. EAST COLLECTORS DUCT

Avg $V = 0.0$ m/s
$A = 0.0271$ m²
$\dot{m} = 0.0$ m³/s



2. WEST COLLECTORS DUCT

$V = 0.0$ m/s
$A = 0.0774$ m²
$\dot{m} = 0.0$ m³/s



3. HOUSE DUCT

$V = 2.86$ m/s
$A = 0.0734$ m²
$\dot{m} = 0.210$ m³/s

4. BLOWER DUCT: $V = 0$ m/s, $A = 0.0903$ m²; $\dot{m} = 0.00$ m³/s

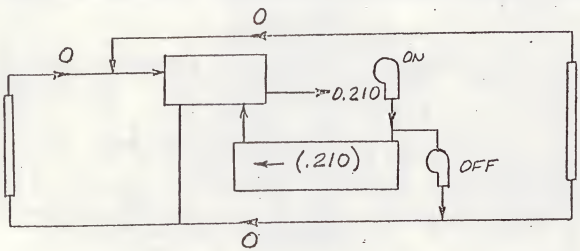
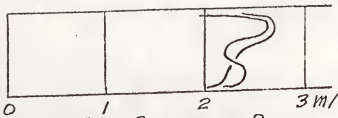


FIGURE A1-4 MODE #3 STORAGE HEAT TO HOUSE

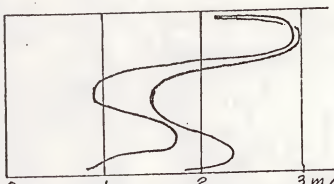


1. EAST COLLECTORS DUCT

Avg $V = 2.39$ m/s

$A = 0.0271$ m^2

$\dot{m} = 0.065$ m^3/s

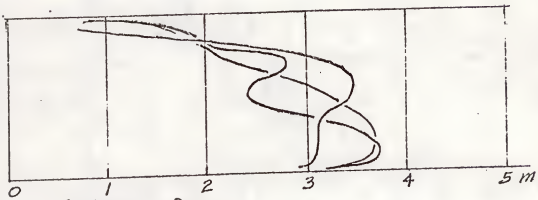


2. WEST COLLECTORS DUCT

$V = 1.87$ m/s

$A = 0.0774$ m^2

$\dot{m} = 0.145$ m^3/s



3. HOUSE DUCT

$V = 2.90$ m/s

$A = 0.0734$ m^2

$\dot{m} = 0.213$ m^3/s

4. BLOWER DUCT: $V = 1.52$ m/s, $A = 0.0903$ m^2; $\dot{m} = 0.137$ m^3/s

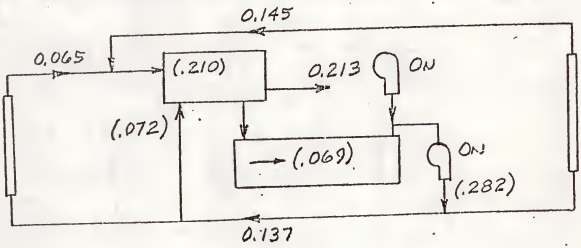
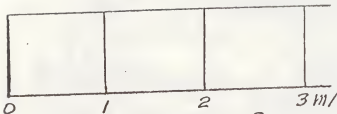


FIGURE AI-5 MODE # 4 SOLAR HEAT TO HOUSE

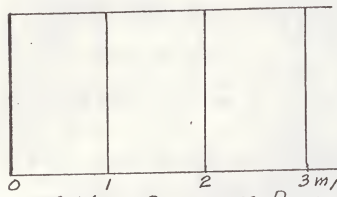


1. EAST COLLECTORS DUCT

Avg $V = 0.0$ m/s

$A = 0.0271$ m²

$\dot{m} = 0.0$ m³/s

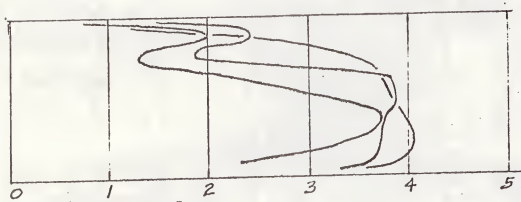


2. WEST COLLECTORS DUCT

$V = 0.0$ m/s

$A = 0.0774$ m²

$\dot{m} = 0.0$ m³/s



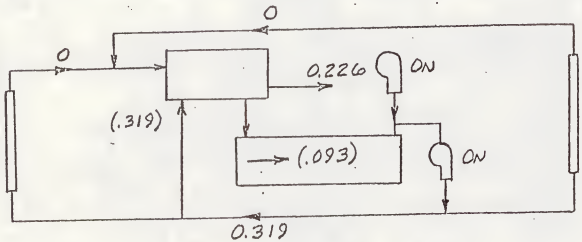
3. HOUSE DUCT

$V = 3.08$ m/s

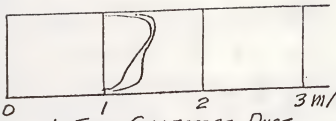
$A = 0.0734$ m²

$\dot{m} = 0.226$ m³/s

4. BLOWER DUCT: $V = 3.53$ m/s, $A = 0.0903$ m²; $\dot{m} = 0.319$ m³/s



— AT   Mode #5 WOOD / ELECTRIC HEATING

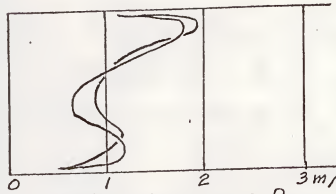


1. EAST COLLECTORS DUCT

Avg $V = 1.35$ m/s

$A = 0.0271$ m^2

$\dot{m} = 0.037$ m^3/s

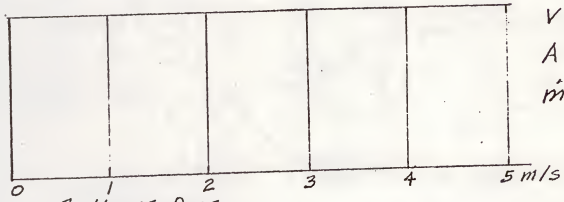


2. WEST COLLECTORS DUCT

$V = 1.15$ m/s

$A = 0.0774$ m^2

$\dot{m} = 0.089$ m^3/s



3. HOUSE DUCT

$V = 0.0$ m/s

$A = 0.0734$ m^2

$\dot{m} = 0.0$ m^3/s

4. BLOWER DUCT: $V = 3.43$ m/s, $A = 0.0903$ m^2; $\dot{m} = 0.310$ m^3/s

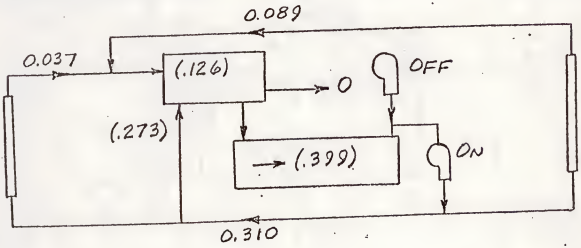
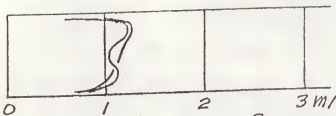


FIGURE AI-7 MODE #6 SOLAR & WOOD HEAT TO STORAGE

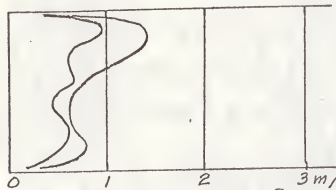


1. EAST COLLECTORS DUCT

Avg $V = 1.15$ m/s

$A = 0.0271$ m²

$\dot{m} = 0.031$ m³/s

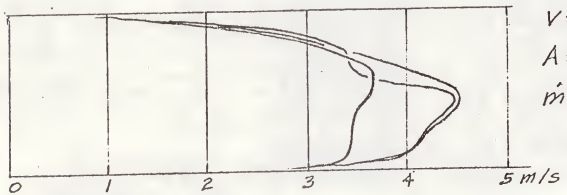


2. WEST COLLECTORS DUCT

$V = 0.722$ m/s

$A = 0.0774$ m²

$\dot{m} = 0.056$ m³/s



3. HOUSE DUCT

$V = 3.71$ m/s

$A = 0.0734$ m²

$\dot{m} = 0.272$ m³/s

4. BLOWER DUCT: $V = 3.55$ m/s, $A = 0.0903$ m²; $\dot{m} = 0.321$ m³/s

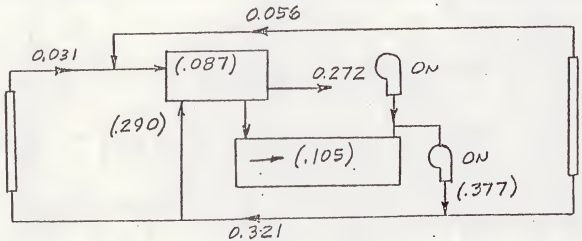


FIGURE AI-8 MODE #7 SOLAR & WOOD HEATING

APPENDIX II

ENERGY EQUATIONS

APPENDIX II - Energy Equations

Theory

The power (energy per unit time) delivered by any system component is given by the first law of thermodynamics. This law is expressed in mathematical form as

$$P = \dot{m} c_p (T_o - T_i),$$

where P = power (kW)

$\dot{m}$ = mass flow rate through the component (kg/s)

c_p = specific heat (watt-sec/gm - °C)

T_o = exit temperature (°C)

T_i = entrance temperature (°C)

The data acquisition system obtains all relevant temperatures and the operational status of the system. Status is characterized by three numbers which are either unity or zero:

$S_1 = 1$ means damper #1 is open

$S_2 = 1$ means damper #2 is open

$S_3 = 1$ means damper #3 is open

When a status number is zero, the corresponding damper is closed. The three dampers are located as indicated in Figure AI-1.

Since the flow rates are, in general, different for all the operational modes, a set of equations was obtained which automatically resulted in storage of the appropriate flow rates in the data acquisition computer.

System Equations

Since all power equations contain mass flow and specific heat in product form, that product was obtained for every mode:

$$W = \dot{m} c_p \ (\text{kW}/^\circ\text{C})$$

This product is called the specific energy flow. These quantities are displayed in the table on the following page, along with the corresponding status numbers for each mode.

Mode	S_1	S_2	S_3	W_1	W_2	W_3	W_4
1	0	1	0	0	.079	.133	.140
2	1	0	0	0	0	0	.379
3	0	0	1	.254	0	0	.254
4	0	1	1	.258	.079	.176	.166
5	1	0	1	.274	0	0	.386
6	1	1	0	0	.045	.108	.375
7	1	1	1	.329	.038	.068	.389
8	0	0	0	0	0	0	0

where W_1 = specific energy flow in the house heating duct,

W_2 = specific energy flow from the east collectors,

W_3 = specific energy flow from the west collectors, and

W_4 = specific energy flow through the plenum.

Using the above table, the following equations were derived:

$$W_1 = (.254 + .028S_1 + .004S_2 + .051S_1S_2)\, S_3$$

$$W_2 = (.079 - .034S_1 - .007S_1S_3)\, S_2$$

$$W_3 = (.133 - .025S_1 + .043S_3 - .083\, S_1S_3)S_2$$

$$W_4 = (.379 - .144S_2 - .247S_3 + .235S_2S_3)S_1 + .140S_2 + .254S_3 - .228S_2S_3$$

These specific energy flow rates are the correct values for any mode of operation. They are used to determine powers using the following temperatures:

T_1 = House blower outlet temperature

T_2 = House heat duct temperature

T_3 = East collector outlet temperature

T_4 = East collector inlet temperature

T_5 = West collector outlet temperature

T_6 = West collector inlet temperature

T_7 = Temperature in duct between plenum and storage

T_8 = Main blower inlet temperature

House heat load:

$$Q_1 = W_1 (T_2 - T_1)$$

East collectors' power:

$$Q_2 = W_2 (T_3 - T_4)$$

West collectors' power:

$$Q_3 = W_3 (T_5 - T_6)$$

Total collector power:

$$Q_4 = Q_2 + Q_3$$

Solar energy direct to living space (modes #4,7):

$$Q_5 = [\ .079(T_3 - T_1) + .176(T_5 - T_1)] (1 - S_1) S_2 S_3 + [\ .038(T_3 - T_1) + .068(T_5 - T_1)] S_1 S_2 S_3$$

The status factors were added here to account for the two modes involved.

Energy added to or taken from the storage box could not be directly measured. A large number of temperature probes in the rock storage would be required to do that. Storage energy changes were computed from air flows through the storage using the first law equation.

Solar energy stored (modes #1,4,7):

$$Q_6 = S_2(T_7 - T_8) (.273 - .273 S_1 - .190 S_3 + .317 S_1 S_3)$$

Energy delivered from storage (mode #3):

$$Q_7 = .254(T_1 - T_7) (1 - S_1)(1 - S_2) S_3$$

Wood energy to living space (mode #5):

$$Q_8 = .274(T_2 - T_8) S_1 S_3 (1 - S_2)$$

Wood energy to storage (mode #2):

$$Q_9 = .379(T_7 - T_8) S_1 (1 - S_2)(1 - S_3)$$

APPENDIX III

SELECTED HOURLY PERFORMANCE DATA WITH DAILY SUMMARY

TABLE 1

DAILY PERFORMANCE SUMMARY FOR THE TRAILER PROJECT 1/ 14/79

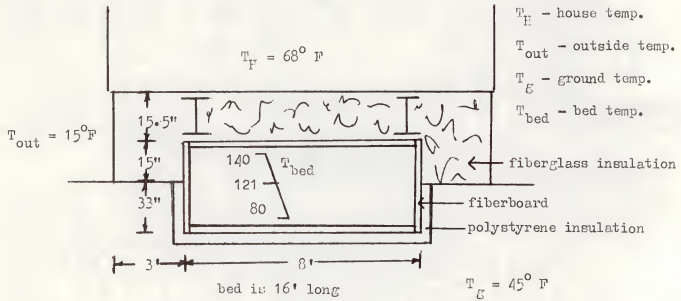
HR	SOLAR INSO (MJ)	SOLAR OUTPUT (MJ)	SOLAR STORE (MJ)	WOOD STORE (MJ)	STORE HOUSE (MJ)	SOLAR HOUSE (MJ)	WOOD HOUSE (MJ)	ELECT HOUSE (MJ)	SUMM INPUT (MJ)	HEAT LOAD (MJ)	HOUSE TEMP (C)	AMBT TEMP (C)	COLL OUT (C)	PLEN TEMP (C)	PLEN STOR (C)	TO HOUSE (C)	CRAWL SPACE (C)	FR HOURLY	HS	CL	WD STATUS
1	.0	.0	.0	.0	.0	.0	4.7	6.3	11.0	18.6	26.7	-19.8	36.1	53.3	10.5	13.4	11.4	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	3.2	3.6	6.9	18.8	26.7	-20.2	36.9	45.2	10.3	13.7	11.6	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	4.1	4.1	19.3	26.4	-21.7	23.5	37.2	10.1	13.5	11.4	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	4.2	4.2	18.6	26.1	-20.5	19.8	31.2	10.1	13.6	11.6	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	3.9	3.9	18.8	25.8	-21.2	15.9	27.3	9.9	13.5	11.3	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	3.8	3.8	19.2	25.4	-22.8	11.7	24.7	9.8	13.1	10.7	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	4.3	4.3	19.3	24.9	-23.3	9.2	22.8	9.6	12.6	10.2	.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	3.9	3.9	19.0	23.5	-24.0	8.2	21.5	9.5	12.4	10.0	.0	.0	.0	.0
9	6.4	.0	.0	.0	.0	.0	.0	3.9	3.9	18.3	22.8	-23.0	8.2	20.8	9.4	12.2	9.6	.0	.0	.0	.0
10	24.5	.0	.0	.0	.0	.0	.0	4.8	4.8	17.3	22.9	-20.3	10.1	21.0	9.4	12.4	9.3	.0	.0	.0	.0
11	59.7	.0	.0	.0	.0	.0	.0	4.8	4.8	16.4	24.2	-16.8	22.6	38.5	9.7	12.5	10.2	.0	.0	.0	.0
12	87.4	.0	.0	.0	.0	.0	6.2	2.3	8.5	15.8	23.8	-15.6	44.1	60.9	10.6	12.7	11.8	.0	.0	.0	.0
13	63.9	4.3	.8	.0	.0	3.5	.0	1.5	5.0	6.4	2.0	-14.1	45.2	67.1	16.8	14.6	12.5	.0	.0	.2	.0
14	50.1	3.1	1.0	.0	.0	2.0	.0	1.7	3.7	14.7	24.0	-12.7	39.4	54.5	23.4	16.5	13.4	.0	.0	.2	.0
15	14.9	.0	.0	.0	.0	.0	6.2	1.9	8.2	15.4	23.6	-15.0	41.7	61.1	16.0	14.1	13.7	.0	.0	.0	.0
16	7.5	.0	.0	.0	.0	.0	7.6	2.5	10.0	15.7	23.2	-16.1	47.1	67.8	14.5	13.9	13.7	.0	.0	.0	.0
17	3.2	.0	.0	.0	.0	.0	6.6	2.2	8.8	15.4	22.4	-16.0	45.5	62.8	13.6	14.2	13.4	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	7.8	1.1	9.0	16.0	22.2	-17.7	51.3	69.2	13.1	14.0	13.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	7.6	1.2	8.8	15.8	21.9	-17.7	51.4	68.0	12.7	14.1	12.9	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	5.5	1.5	7.1	15.2	20.6	-17.3	44.3	57.7	12.2	13.9	12.9	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	3.3	1.2	4.5	14.3	18.9	-17.0	34.3	45.7	11.8	13.8	12.7	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	.0	1.2	1.2	13.3	17.2	-16.2	28.8	36.7	11.5	13.7	13.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	.0	1.2	1.2	12.8	15.7	-16.2	22.4	29.4	11.3	13.6	13.1	.0	.0	.0	.0
0	.0	.0	.0	.0	.0	.0	.0	2.3	2.3	12.6	15.3	-16.3	17.5	24.3	11.1	13.5	13.2	.0	.0	.0	.0
	317.5	7.4	1.8	.0	.0	5.5	58.7	69.4	133.7	386.9	21.9	-18.4	29.6	43.8	11.9	13.6	11.9	.0	.0	.0	.0

APPENDIX IV

(1) CALCULATED HEAT LOSS FROM STORAGE
(2) CALCULATED HEAT LOSS FROM HOUSE
(3) LOG OF WOOD USE

Appendix IV: Calculation of Heat Loss from Storage

First the heat loss will be calculated for the construction shown below with fiberglass insulation filling the space between the bed and skirting and the bed and the mobile home.



Thermal conductivities (K)

fiber board	K = .34 BTU-in/hr-ft^2-^{o} F
polystyrene	K = .19
fiberglass	K = .27

Due to the large amount of fiberglass insulation above and around the bed the ground immediately around the bed should be at a uniform temperature, approximately 45^o F for Bozeman.

The fiber board will be .5 in thick and 2 in polystyrene insulation surrounds the bed below ground level.

R (resistance) values

$$R = \frac{t}{K} \qquad t \text{ - material thickness (in)}$$

for the bed below ground

$$R_G = \frac{.5}{.34} + \frac{2}{.19} = 12.0 \text{ hr-ft}^2\text{-}^o\text{F/ BTU}$$

for the sides of the bed above ground

$$R_S = \frac{.5}{.34} + \frac{36}{.27} = 134.8$$

for the bed roof (R value of the floor of the mobile home is R-30)

$$R_R = \frac{.5}{.34} + \frac{15.5}{.27} + 30 = 88.9$$

Heat flows (q)

$$q = \frac{1}{R} A \Delta T$$

A- Area (ft^2)

ΔT- differential temperature ($^\circ$ F)

into the ground

$$q_G = \frac{1}{12} (8 \times 16) (80-45) + \frac{1}{12} [33/12 (2 \times 16 + 2 \times 8)] \times \left[\frac{121 + 80}{2} - 45\right]$$

$$= 983.8 \text{ BTU/hr}$$

out the sides

$$q_S = \frac{1}{134.8} [15/12 (2 \times 16 + 2 \times 8)] \left[\frac{140 + 121}{2} - 15\right]$$

$$= 51.4$$

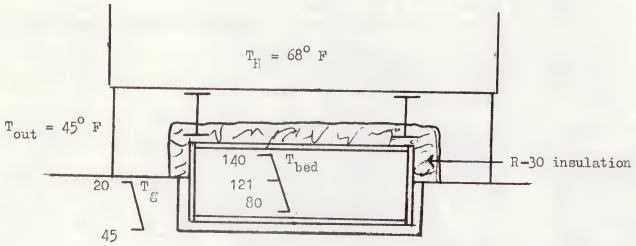
out the roof

$$q_R = \frac{1}{88.9} (8 \times 16) (140 - 68) = 103.7$$

The total heat loss is then

$$q_T = 983.8 + 51.4 + 103.7 = 1100 \text{ BTU/ hr}$$

Now the heat loss will be calculated for the case where a standard R-30 insulation is installed around the bed above ground as shown below.



Because far less insulation surrounds the side of the bed, the ground immediately around the bed would not be at a uniform temperature; it would become cooler near the surface.

R values

R_q - same as before = 12.0 hr-ft^2- ° F/ BTU

$$R_S = R_R = \frac{.5}{.34} + 30 = 31.5$$

Heat flows (q)

into the ground

$$q_q = \frac{1}{12} (8 \times 16) (80 - 45) + \frac{1}{12} [33/12 (2 \times 16 + 2 \times 8)] \times [\frac{121 + 80}{2} - \frac{20 + 45}{2}]$$

$$= 1121.3 \text{ BTU/ hr}$$

out the sides

$$q_S = \frac{1}{31.5} \left[15/12 \ (2 \times 16 + 2 \times 8) \right] \left[\frac{140 + 121}{2} - 15 \right]$$

$$= 220.0$$

out the roof

$$q_R = \frac{1}{31.5} (8 \times 16) (140 - 15) = 507.9$$

Total heat loss

$$q_T = 1121.3 + 220.0 + 507.9 = 1800 \text{ BTU/hr}$$

% increase in heat loss

$$\frac{1800 - 1100}{1100} \times 100 = 64\%$$

	R	U(Btu/hr ft^2 ^{o}F)	Area(sq.ft)	U X A
Roof	40.2	.025	784	19.6
Walls	20.5	.048	837	40.2
Floor	22.5	.044	784	34.5
Windows	1.81	.55	105.6	58
Doors	3	.33	37	12.2

Infiltration

(One air change/hour, 5,488ft^3)

5488ft^3 X 1hr X.018 = 98.8

Total Heat Load (Btu/hr^{o}F) 263.3

TRAILER WOOD CONSUMPTION LOG

M	D	H	Weight(kg)	Heat(MJ)	
1	28	9	6.8	13.6	
		10	2.7	5.4	19.0
	29	18	13.6	27.2	
		21	6.8	13.6	20.4
	30	4	6.8	13.6	
		7	9.1	18.2	
		19	9.1	18.2	50.0
	31	1	11.4	22.8	
		7	9.1	18.2	
		10	9.1	18.2	
		15	2.7	5.4	
		18	2.7	5.4	70.0
2	1	7	9.1	18.2	
		9	2.7	5.4	
		10	2.7	5.4	
		16	11.4	22.8	
		18	2.7	5.4	
		20	9.1	18.2	
		21	4.5	9.0	
		22	4.5	9.0	93.4
	2	1	2.7	5.4	
		2	4.5	9.0	
		7	4.5	9.0	
		17	6.8	13.6	
		18	4.5	9.0	
		20	4.5	9.0	
		22	4.5	9.0	58.6
	3	1	4.5	9.0	
		3	2.7	5.4	
		4	6.8	13.6	
		6	2.7	5.4	
		8	6.8	13.6	
		20	8.2	16.4	
		22	3.6	7.2	70.6
	4	9	5.5	11.0	
		10	2.7	5.4	
		13	4.5	9.0	25.4
	5	7	3.6	7.2	
	6	12	4.1	8.2	
		16	3.2	6.4	14.6
	7		—	—	
	8		—	—	
	9		—	—	
	10		—	—	
	11	6	4.5	9.0	
		9	6.4	12.8	21.8

M	D	H	Weight(kg)	Heat(MJ)	
2	12		—	—	
	13	8	6.8	13.6	
		19	5.9	11.8	25.4
	14	16	6.8	13.6	
		21	5.0	10.0	23.6
	15	5	5.5	11.0	
		9	5.9	11.8	
		10	5.5	11.0	33.8
	16	9	7.3	14.6	
		20	7.7	15.4	30.0
	17		—	—	
	18	10	6.8	13.6	
	19		—	—	
	20	7	4.1	8.2	
	21	3	4.5	9.0	
	22	8	4.5	9.0	
		21	8.2	16.4	25.4
	23	9	7.3	14.6	
	24		—	—	
	25		—	—	
	26	21	6.4	12.8	
	27		—	—	
	28	10	6.4	12.8	
		13	5.5	11.0	
		17	5.0	10.0	
		19	4.5	9.0	42.8
3	1		—	—	
	2		—	—	
	3		—	—	
	4		—	—	
	5		—	—	
	6	11	4.1	8.2	
		13	2.7	5.4	13.6
	7		—	—	
	8		—	—	
	9	8	6.8	13.6	

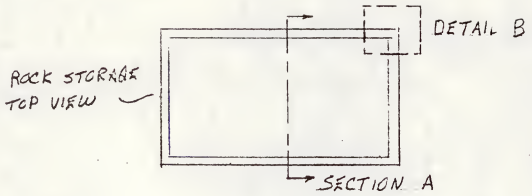
386.1kg/Total

Total Days 41 or 9.4kg/day avg.
Total Days of Use = 24 or 16.1kg/day avg.

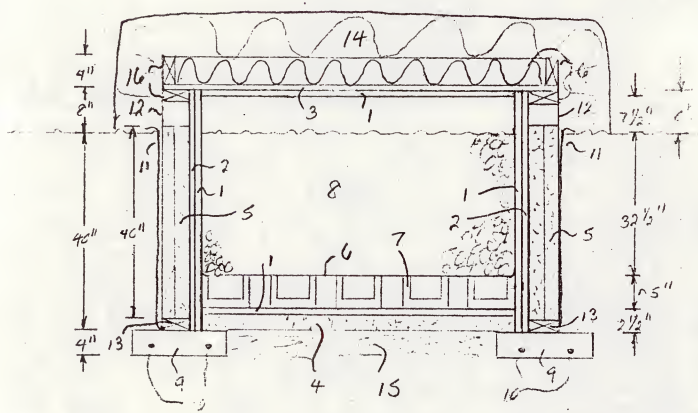
APPENDIX V

CONSTRUCTION DETAILS OF ROCK BIN HEAT STORAGE

ROCK STORAGE DETAILS



SECTION A

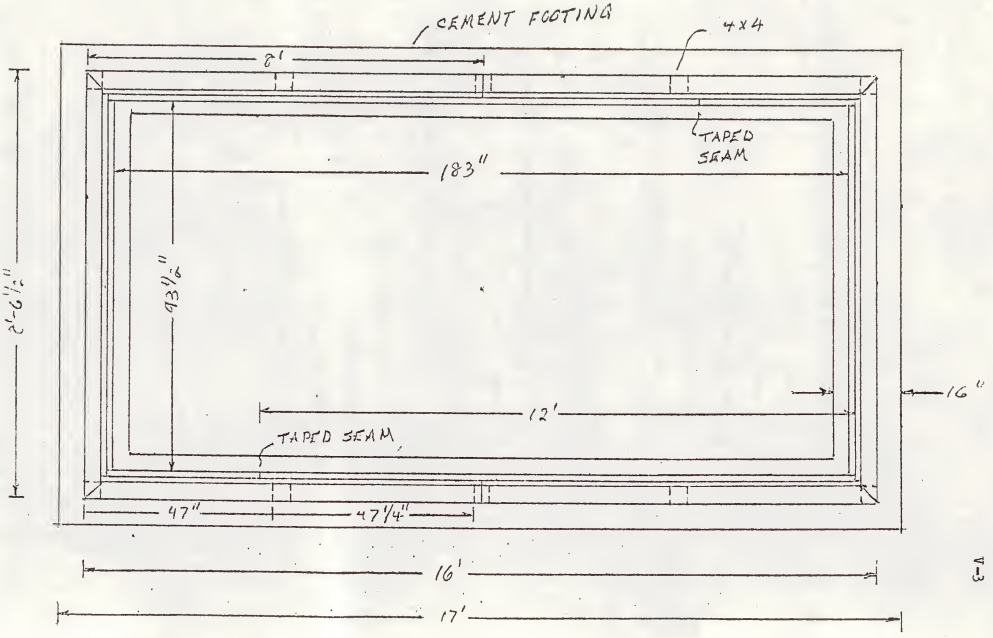


Section A

Parts and materials

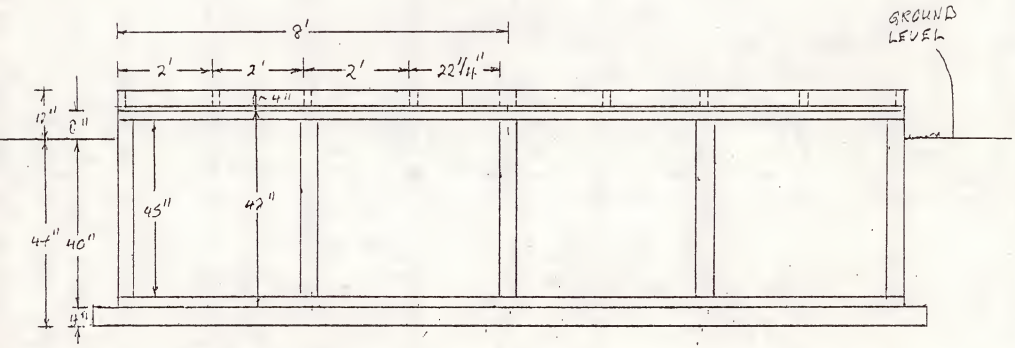
- ½ inch type x drywall, all seams taped and filled, Seams should overlap seams of fiber board and plywood by at least 4".
- ½ inch exterior grade fiber board
- ½ inch exterior grade plywood
- 2" polystyrene bead insulation (white)
- 4" polystyrene bead insulation (white)
- metal lath, USG Jr. diamond mesh, 3.4 lb/yd^2. Adjoining pieces overlapped at least 6", edges turned up at wall of storage box at least 6"
- bond beam block, 7 5/8 x 7 5/8 x 15 5/8 "
  Bond laid parallel to main air flow,
  block separated by 3-4", placed up against the wall of storage box.
- washed river rock, 3/4 - 1½"diameter, not over 35% fractured rock
- 4 x 16"cement footing
- rebarb, ½" off the ground, 4" from the side
- 6 mil, polyethylene vapor barrier, run under storage and on sides to above ground, at least 6" overlap
- 4 x 4" cedar or treated fir posts
- 2 x 4" cedar or treated fir
- 12" fiberglass batt insulation
- fill dirt, tamped flush with top of footings
- 2 x 4" fir

TOP VIEW OF STRUCTURAL PIECES (LID REMOVED)

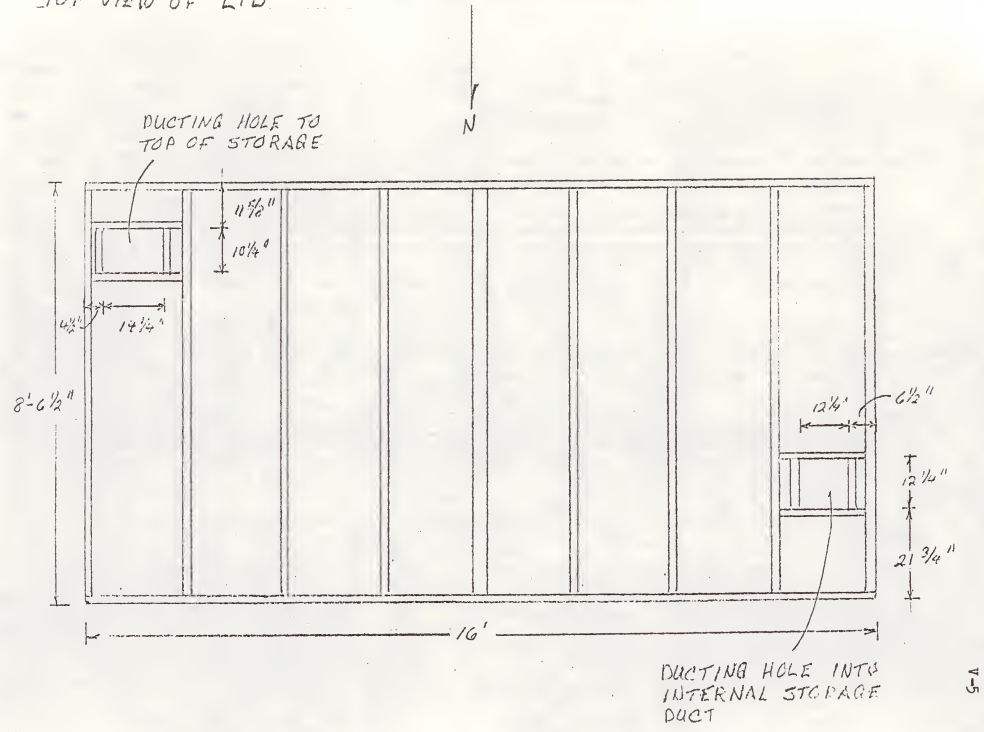


3-4

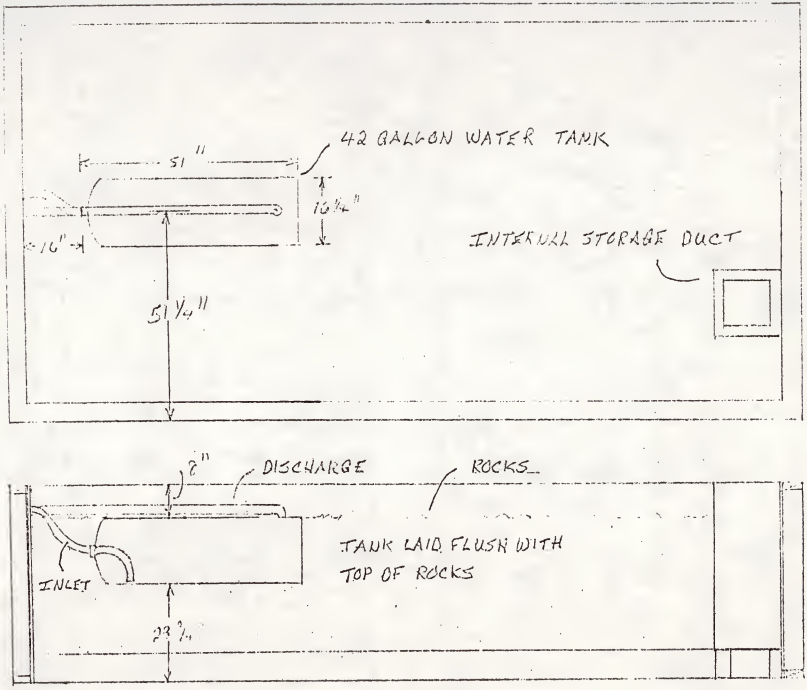
SIDE VIEW OF STRUCTURAL PIECES



TOP VIEW OF LID

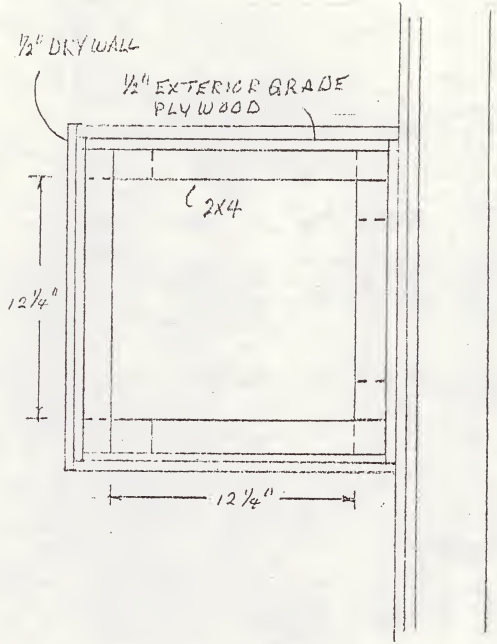


INTERNAL STORAGE DUCT
AND WATER TANK LOCATION

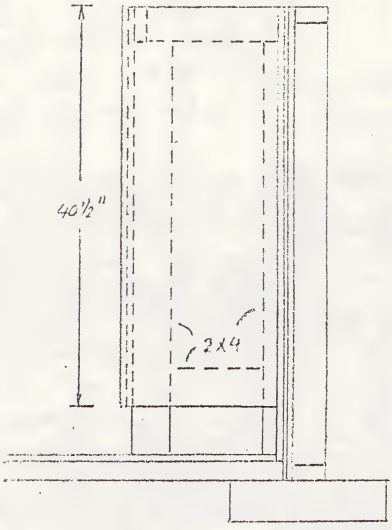


9-A

TOP VIEW OF
INTERNAL DUCT



SIDE VIEW

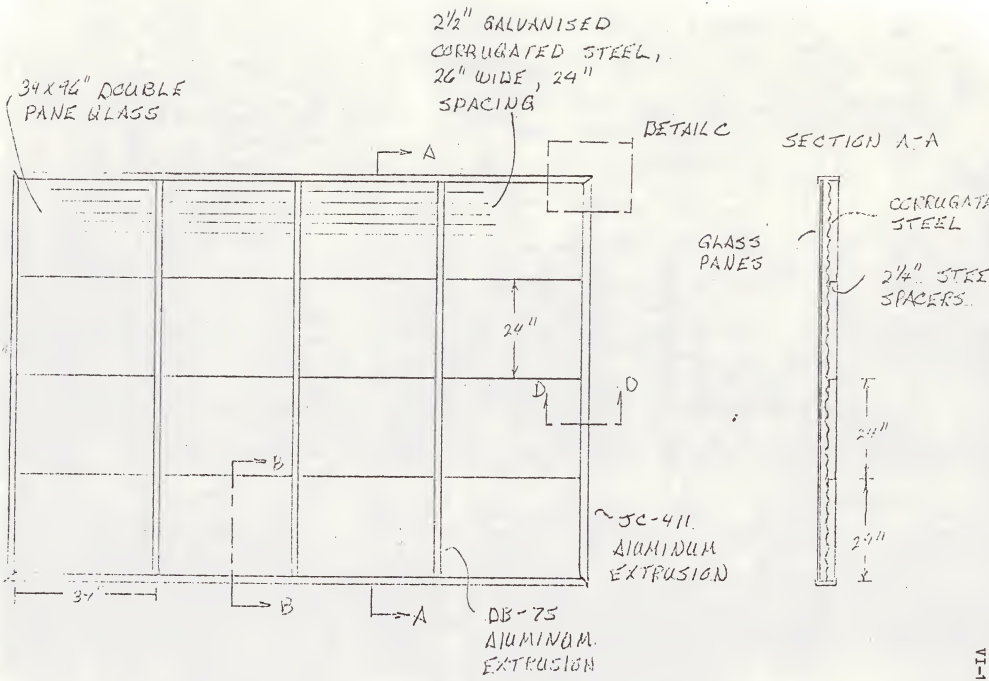


STORAGE BOX
WALL

APPENDIX VI

COLLECTOR CONSTRUCTION DETAILS

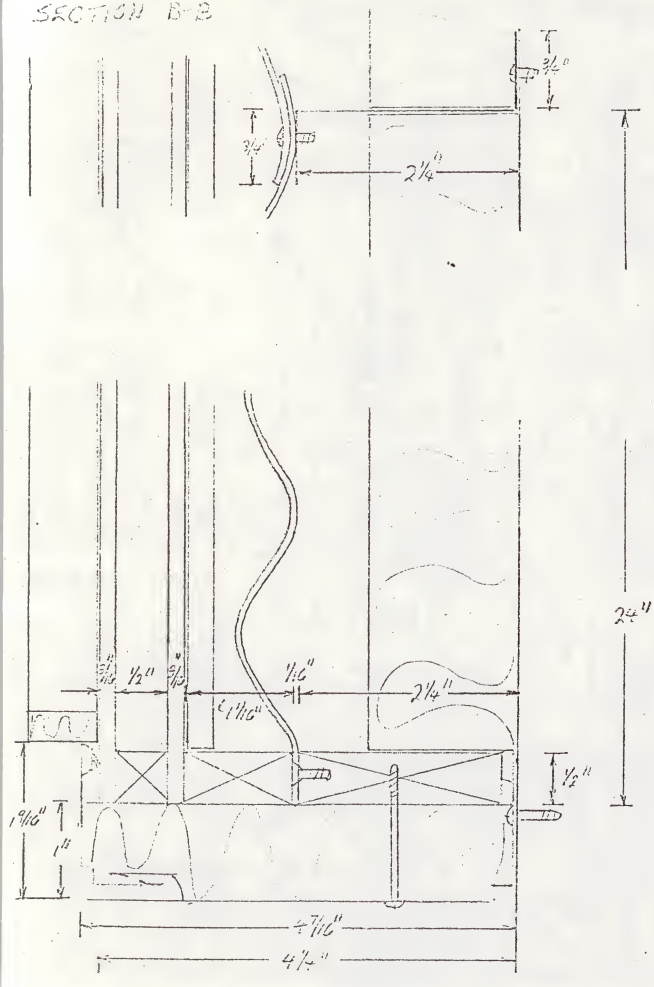
COLLECTOR DETAILS



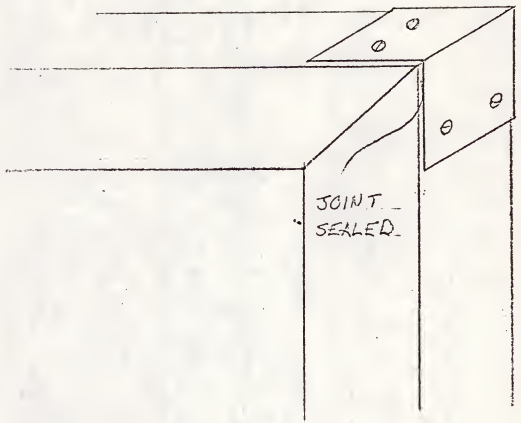
SECTION B-B

GLASS SPACER
END OF EXTRUSION PLUGGED WITH FIBERGLASS
DB-75 EXTRUSION
GLASS PANES
DB-75 EXTRUSION
2½" CORRUGATED STEEL, 26" WIDE, 24" SPACING
JOINT SEALED
ALUMINUM FOIL BACKED
INSULATION AND BOARD FILLER
WALL OF MOBILE HOME
12 GAGE STEEL CHANNEL SPACER
JOINT SEALED
CONTINUOUS WOODEN SPACER
NEOPRENE GASKET
E-44 ALUMINUM EXTRUSION
FIBERGLASS BOARD INSULANT OR PLEX

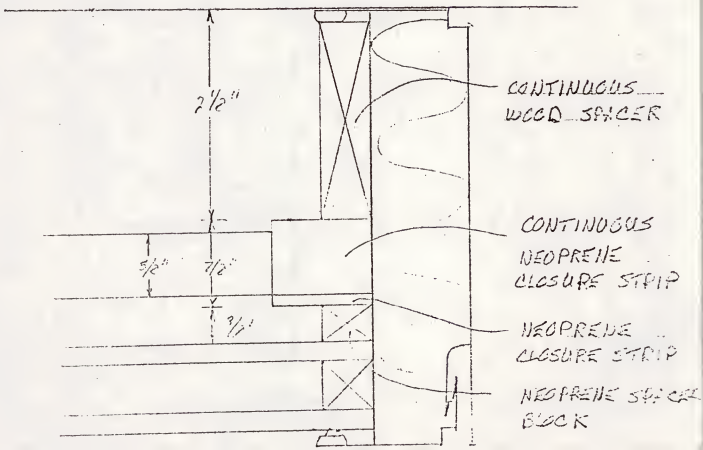
SECTION B-B



DETAIL C



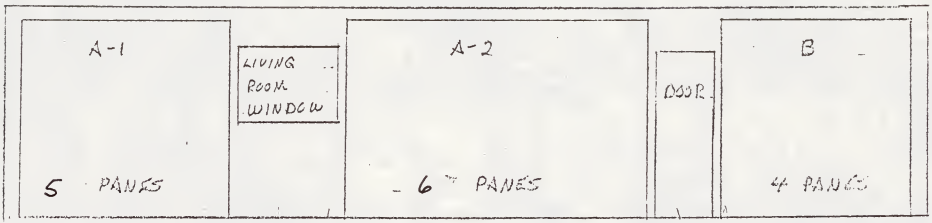
SECTION D-D



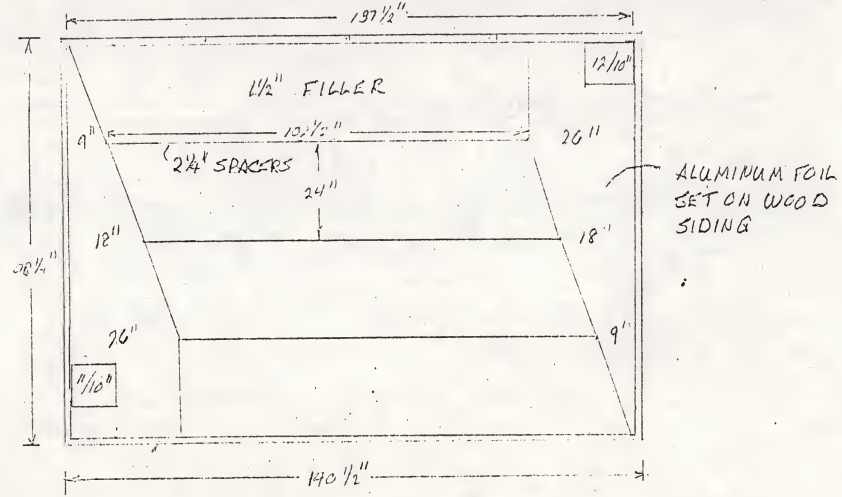
COLLECTOR FILLER AND
CHANNEL STEEL SETTING
(NO SCALE)

PANES = 34 x 96"

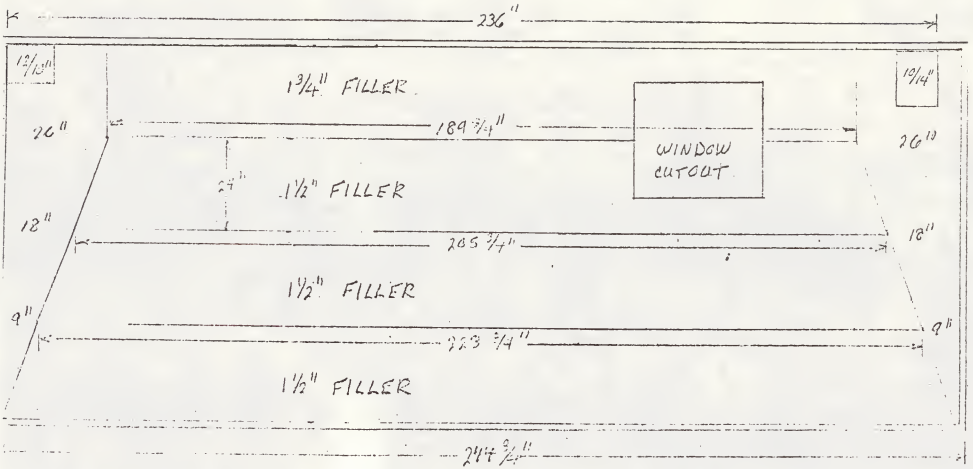
WEST ←



COLLECTOR A-1, 4 PANES (PANES AND ABSORBER PLATE REMOVED)

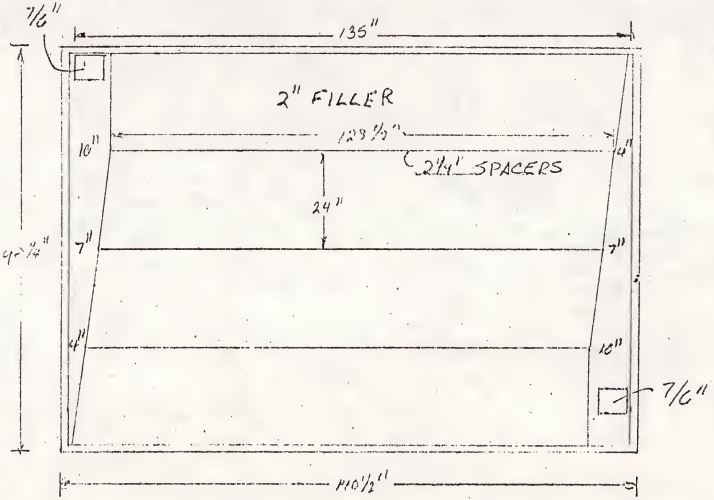


COLLECTOR A-2, 7 PANES

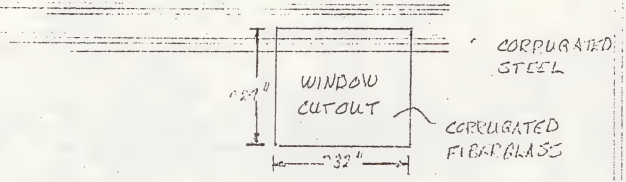


VI-7

COLLECTOR B, 4 PANES



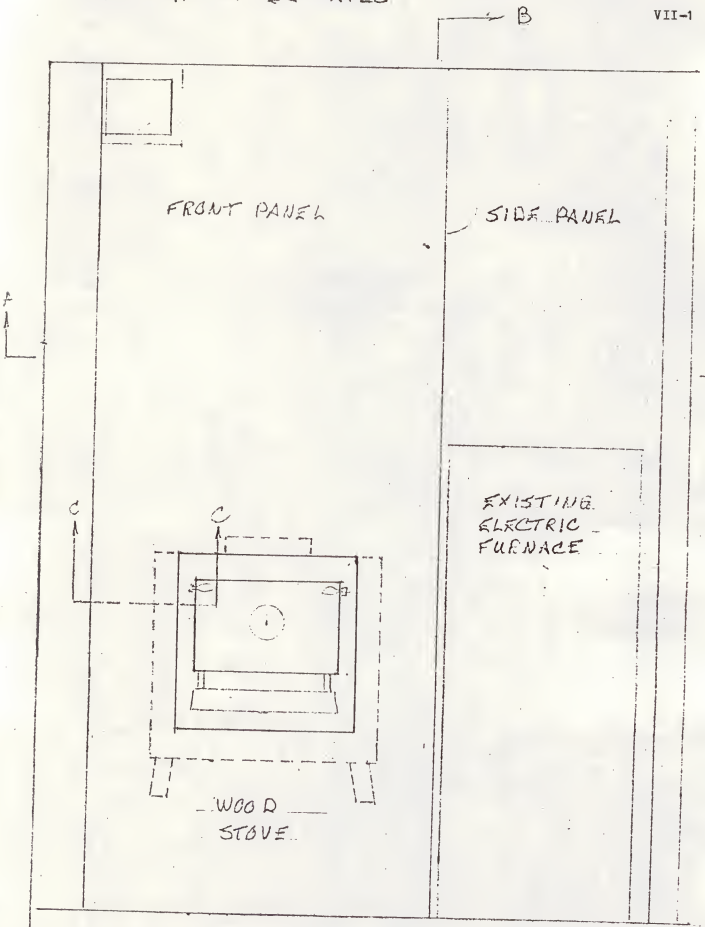
COLLECTOR A-2 WINDOW CUTOUT



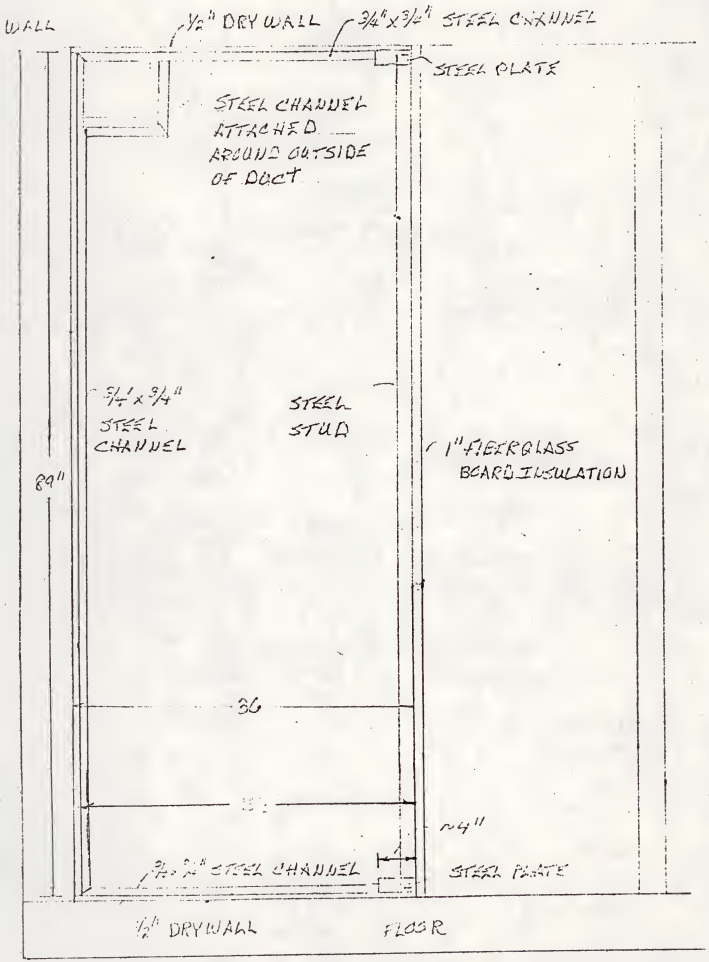
APPENDIX VII

PLENUM ROOM DETAILS

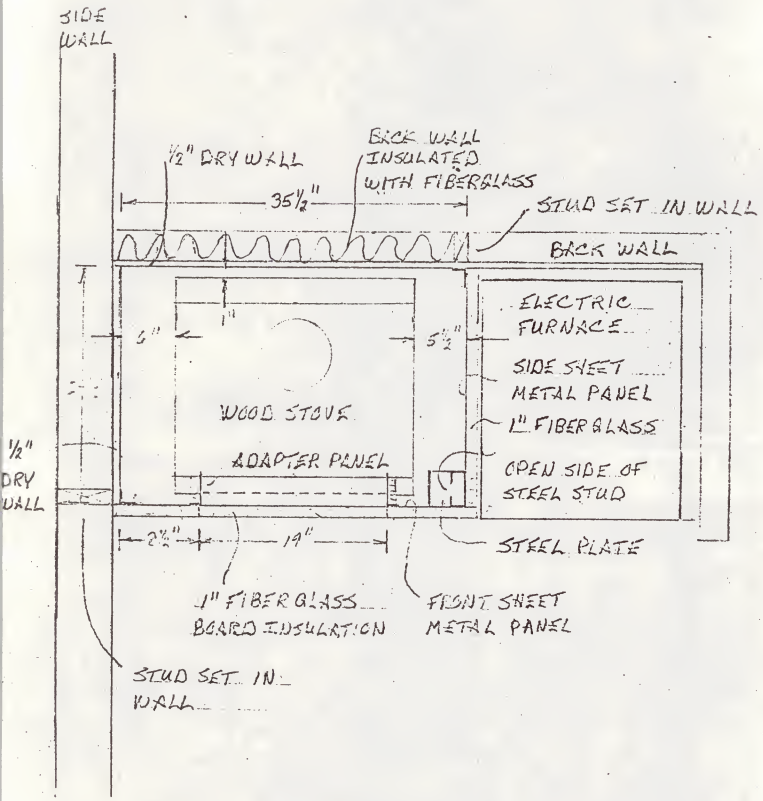
PLENUM ROOM DETAILS



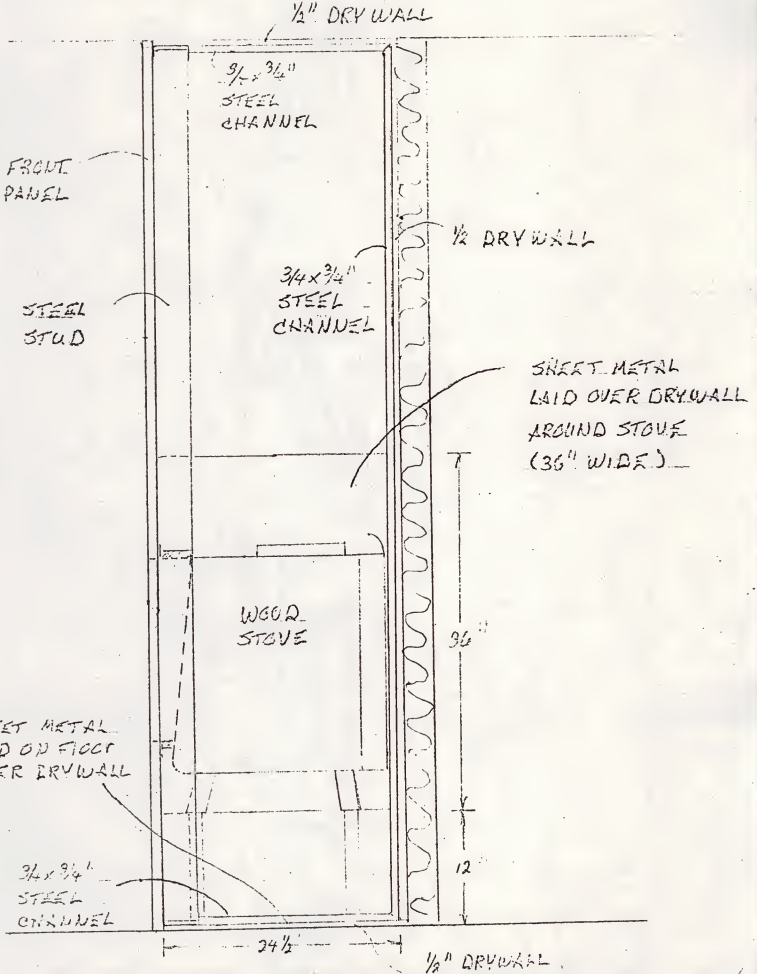
FRONT PLENUM DETAILS



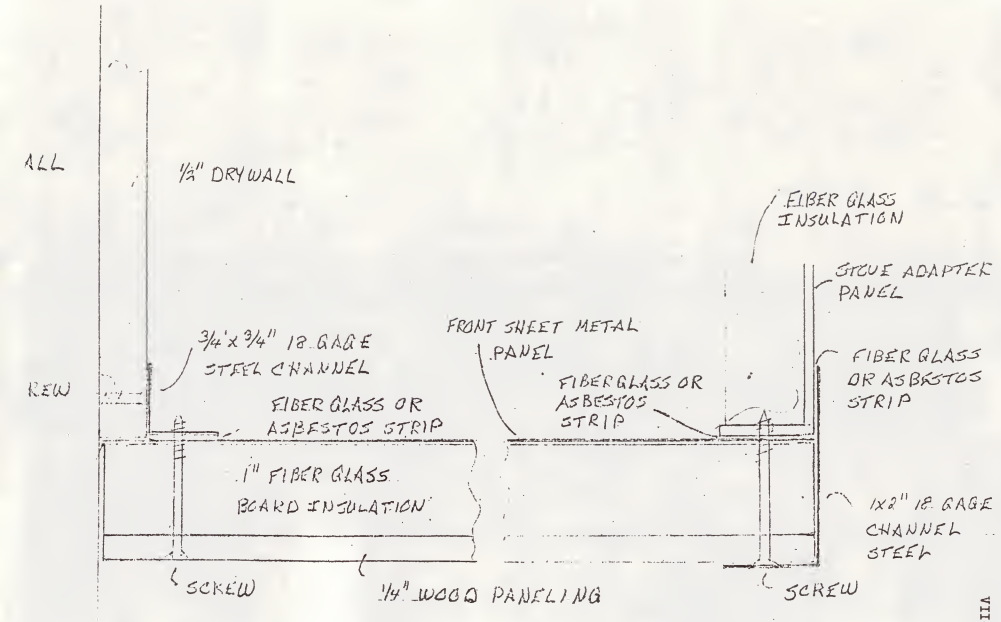
SECTION A-A


SIDE WALL
½" DRY WALL
BRICK WALL INSULATED WITH FIBERGLASS
35½"
STUD SET IN WALL
BRICK WALL
ELECTRIC FURNACE
1"
5"
5½"
SIDE SHEET METAL PANEL
WOOD STOVE
1" FIBERGLASS
ADAPTER PANEL
OPEN SIDE OF STEEL STUD
½" DRY WALL
2½"
19"
STEEL PLATE
1" FIBERGLASS BOARD INSULATION
FRONT SHEET METAL PANEL
STUD SET IN WALL

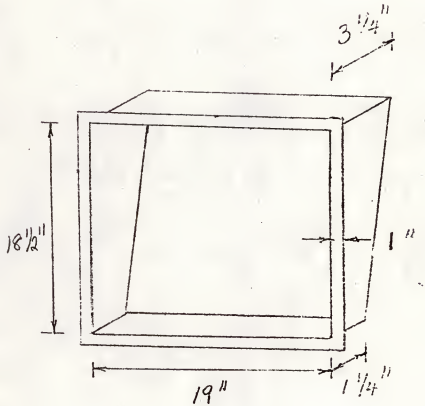
SECTION B-B


½" DRYWALL
¾ x ¾" STEEL CHANNEL
FRONT PANEL
½ DRYWALL
¾ x ¾" STEEL CHANNEL
STEEL STUD
SHEET METAL LAID OVER DRYWALL AROUND STOVE (36" WIDE)
WOOD STOVE
36"
SHEET METAL LAID ON FLOOR OVER DRYWALL
12
¾ x ¾" STEEL CHANNEL
24½
½" DRYWALL

SECTION C-C


ALL
REW
1/2" DRYWALL
3/4"x3/4" 18 GAGE STEEL CHANNEL
FIBER GLASS OR ASBESTOS STRIP
1" FIBER GLASS BOARD INSULATION
SCREW
1/4" WOOD PANELING
FRONT SHEET METAL PANEL
FIBERGLASS OR ASBESTOS STRIP
FIBER GLASS INSULATION
STOVE ADAPTER PANEL
FIBER GLASS OR ASBESTOS STRIP
1x2" 18 GAGE CHANNEL STEEL
SCREW

ADAPTER PANEL DETAIL



1/2" STEEL, WELDED

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